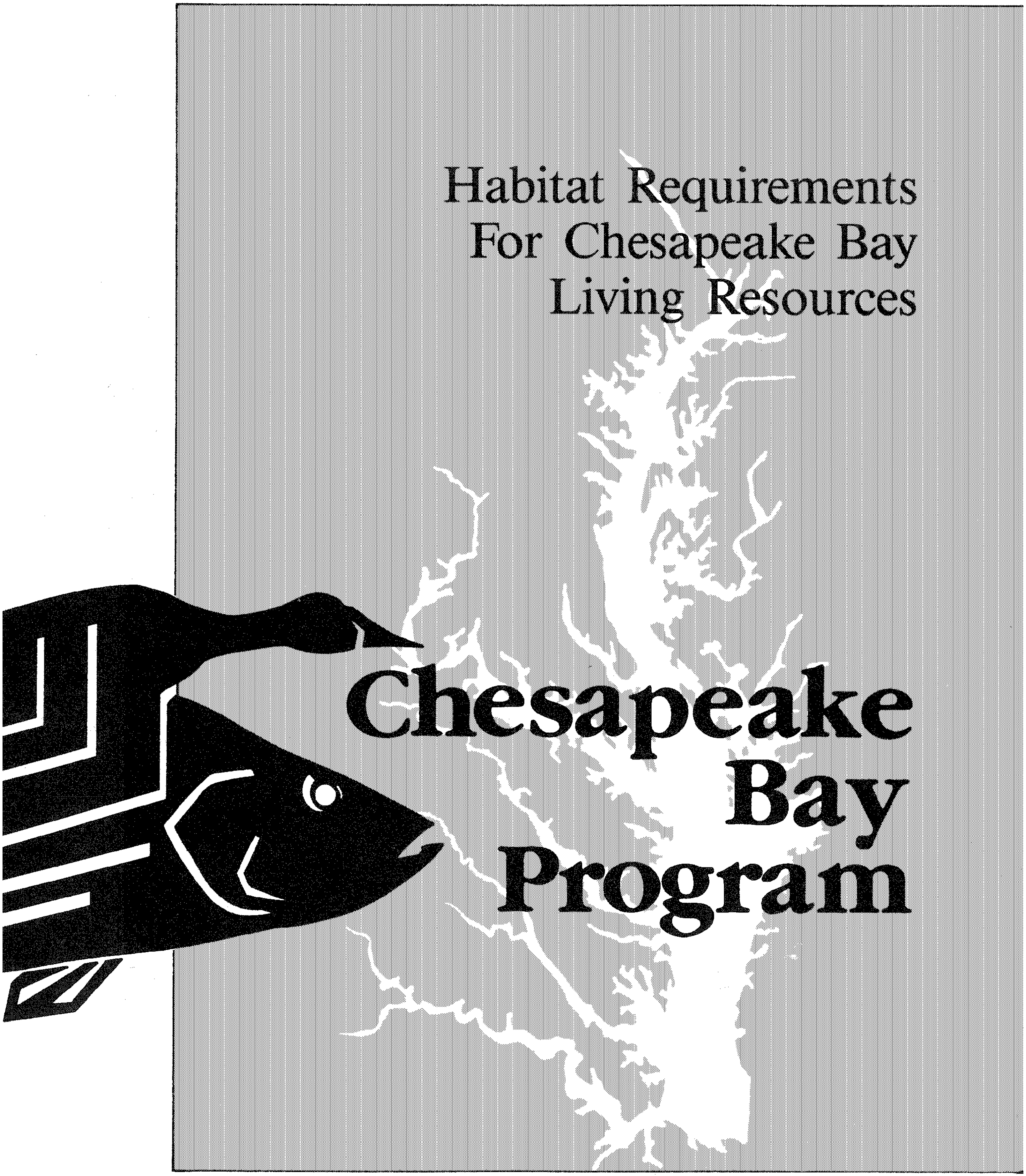
Chesapeake Bay Living Resources Task Force



Habitat Requirements For Chesapeake Bay Living Resources

Chesapeake Bay Program

August 1987

HABITAT REQUIREMENTS
FOR CHESAPEAKE BAY LIVING RESOURCES:
A Report from the Chesapeake Bay Living Resources Task Force

Annapolis, Maryland
August, 1987

DISCLAIMER

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KEY

m = meter
C = celcius
ppt = parts per thousand
KD = light attenuation coefficient
TRC = total residual chlorine
cm/s = centimeters per second
chlor. = chlorophyll
mg/l = milligrams per liter - equivalent to parts per million
ug/l = micrograms per liter - equivalent to parts per billion
LC0 = lethal concentration - 0 percent mortality
LC50 = lethal concentration - 50 percent mortality
um = micron

FOREWORD

The Living Resources Task Force, an ad hoc workgroup of the Chesapeake Bay Program, was charged by the Chesapeake Bay Implementation Committee to develop an approach to define habitat objectives for the living resources of the Bay. The objective of the Task Force in producing this report was to establish a technically defensible approach in setting regional habitat objectives for Chesapeake Bay by initially assembling habitat requirements for individual target species. The scope of this report places limitations on its utility as a planning document for Bay managers. It is intended, however, to summarize the results of the Task Force efforts to date and to provide the basis for future refinement of the habitat objectives approach. This document describes the results of ongoing efforts to identify critical habitat requirements for target species.

Within the context of this report, habitat is defined as the biotic and abiotic conditions upon which the living resources of the Bay depend. Abiotic conditions include factors such as water quality, substrate, circulation patterns, bathymetry, and weather; two dominant factors are salinity and depth. Biotic conditions are governed by variables such as vegetative cover, quality and quantity of prey species, species composition, population density, and primary productivity. The estuarine environment represents a wide range of these conditions which are dynamic in time and space. Although Bay species are tolerant of dynamic natural conditions, their habitats have been altered by man-induced activities; there is evidence that thresholds for tolerating adverse conditions have been exceeded. The Living Resources Task Force has attempted to identify the boundaries of tolerable conditions in the form of habitat requirements.

The report is constructed following the guidelines created to direct the development of living resources habitat requirements. The sections on the Chesapeake Bay ecosystem and the major physical factors affecting the Bay provide the structural framework for all subsequent discussions of the living resources. The representative living resources are a group of organisms that serve as indicators of the Bay's ecological condition. From this group, target species were selected as particularly important for the development of initial habitat requirements. The report includes a set of matrices outlining habitat requirements for critical life stages of the target species as well as range maps of these stages.

A scientific workshop, with invited participants from universities, research institutions, and state and federal agencies, was held to review the initial list of requirements and advise the Living Resources Task Force on critical life stages of the target species and seasonal and geographic distributions of the critical life stages. The workshop proceedings are contained in Appendix C: Report of the Workshop on Habitat Requirements for Chesapeake Bay Living Resources (Connery, 1987).

To guide subsequent efforts in linking living resources to habitat conditions, several recommendations for future tasks are proposed. These include expanding the habitat matrices to encompass requirements for food species on which the target species depend, creating habitat matrices for other representative species, identifying species and population characteristics that could serve as indicators of the Bay's health, and encouraging Bay planners to incorporate habitat requirements into their environmental planning efforts.

This report will be utilized during discussions leading to the signing of the revised Chesapeake Bay Agreement in December 1987. Continued development of habitat and living resource goals will be part of the focus in the implementation of that Agreement.

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INTRODUCTION

Declines in stocks of finfish, shellfish, waterfowl and submerged aquatic vegetation in the Chesapeake Bay have prompted an unprecedented effort by the states and federal government to understand causes of the declines and to explore means of restoring and protecting these stocks. Studies completed in 1983 under the aegis of the Environmental Protection Agency concluded that the decline of important resources was due to deteriorating water quality, particularly nutrient enrichment and contamination by toxic metals and organic compounds (EPA, 1983).

Since 1983, most of the research and planning efforts for restoring and protecting the Chesapeake Bay has focused on documenting the present water quality of the Bay and refining strategies for reducing or preventing further increases in nutrient and contaminant loads. Strategies based primarily upon water quality, however, cannot necessarily ensure the restoration and protection of living resources. The most tangible warning signs of widespread environmental problems in the Bay have been shifts in the relative abundance of living resources. Therefore, living resources serve as excellent indicators of the Bay's recovery for Bay managers and the public.

The abundance and distribution of species within the Bay are related to many variables: climate, natural population cycles, reproductive potential, disease, predation, and the abundance and quality of food and habitat. Human activities impose another set of conditions which both directly and indirectly affect species abundance. Fishing, land and water uses, contaminant discharges, and physical habitat alterations can directly affect important species. Indirect impacts of these activities can result in disruption of food chains and perturbation of the ecological balance of the estuary.

In recognition of these principles, the Chesapeake Bay Program's Implementation Committee established the Living Resources Task Force (LRTF) to develop a living resource-based approach for defining habitat objectives for the Bay. The membership of the LRTF consisted of managers and scientists from federal and state agencies, private industry, and universities. Through a series of meetings at both the managerial and technical levels, the Task Force outlined an approach to establish living resource objectives by first identifying habitat requirements for selected target species. The habitat requirements are intended to provide planners, managers, researchers, and modelers of the Bay with information on the minimum habitat quality needed by the target species and the plants and animals upon which the target species depend for food. These requirements can be used to estimate the feasibility, benefits and potential costs of maintaining and protecting an estuarine environment suitable for the successful reproduction and survival of living resources. Habitat requirements are not meant to be standards or criteria for wastewater discharge permitting or other types of regulatory activities, but they can be used to develop water quality standards for regions of the Bay that are defined in terms of living resource habitat rather than water use.

The relationship between the restoration or protection of living resources and requirements for protecting specified habitats requires clarification. Achievement of the proposed requirements will not necessarily directly result in the establishment of specific population or harvest levels for any of the targeted species. For example, total compliance with requirements for striped bass larvae may not result in an improvement of the annual juvenile index. However, the recovery of species which have declined in Chesapeake Bay and the reestablishment of a balanced ecosystem must be seen as the ultimate measures of success in restoring the quality of Chesapeake Bay. These goals will be unattainable unless certain minimum habitat requirements are achieved.

The Living Resources Task Force used the following sequential guidelines for developing the living resources habitat requirements described in this document:

1. **Representative species** for the Chesapeake Bay were identified for all trophic levels, including plankton, vegetation, benthic organisms, shellfish, finfish, and wildlife;

2. A smaller group of **target species** were identified for immediate development of habitat requirements. Criteria selecting the target species were based upon their commercial, recreational, aesthetic, or ecological significance and the threat to sustained production due to population decline or serious habitat degradation;

3. The **critical life stages** and **critical life periods** for the target species were identified;

4. **Habitat requirement matrices** for the targetted living resources and the species upon which they prey were developed and refined from current scientific literature and recent research findings;

5. **Geographic areas** of the Bay were defined where habitat requirements should be met in order to protect the reproduction and survival of the target species. These areas were based upon present distributions with consideration also given to historical distributions.

The guidelines were not set up to address issues of numerical population objectives or management of fish and game harvests. For most Chesapeake Bay species, neither the total population size nor the information needed to estimate stock sizes is available at present, so realistic objectives for population sizes cannot be set. While meeting habitat criteria may not ensure survival of a species in the face of exploitation, there can be no harvest in the absence of sufficient suitable habitat to support the species. The purpose of this first phase of the Task Force effort is to specify the quality and geographic distribution of Bay habitats necessary for the sustainable reproduction and long-term survival of the target species. In the future, the living resources restoration efforts may also address such issues as:

1. Establishment of additional habitat requirements that support both prey of the target species and other representative species. Special attention should be paid to the planktonic and benthic communities as indicators of ecosystem stress and as support organisms for higher trophic levels;

2. Identification of those characteristics of living resource populations (e.g. distribution and abundance) or of Bay communities (e.g. diversity) that will serve as measures of the Bay's recovery or lack of recovery in response to management actions;

3. Provisions for refining programs for monitoring, living resources and habitat conditions, as well as water quality, and for using computer models of the Bay to predict the effects of actions to improve habitat conditions, such as nutrient reduction strategies;

4. Synthesis of habitat requirements into regional habitat objectives.

THE CHESAPEAKE BAY ECOSYSTEM

Public interest in the environment has centered directly on the Chesapeake Bay's aesthetic and economic values and indirectly on its ecological values. The success of economically-important finfish and shellfish is ultimately dependent on the primary producers of the Bay -- phytoplankton and other organisms that form the base of the Chesapeake's food chain. The animals, plants, and microbes of the Bay are interwoven by a complex of feeding, chemical, and physical interactions. Thus, successful restoration and protection of commercially, recreationally, and ecologically-important species are not solely dependent upon the physical and chemical integrity of habitats: the integrity of the trophic food web supporting these populations is crucial to resource survival and abundance.

Figure 1 is a network diagram of the summer, mesohaline Chesapeake Bay designed by Ulanowicz and Baird (1986). The network is presented as a prototype of the major trophic relationships and energy pathways in the Bay. It has been greatly simplified (in comparison to the real system) by grouping many species. It represents the general pattern of carbon flow (an indicator of food and energy) in the upper Chesapeake Bay during summer. Two basic pathways dominate the estuarine food web. The direct pathway leads from living plants to higher animals. The indirect, or detrital pathway leads from dead organic matter to lower animals then to higher animals. Tidal marsh, benthic, and submerged aquatic vegetation communities are strongly dominated by the detrital pathway.

The following discussion outlines the components of the Chesapeake Bay system and food web. Some of the primary producers of the Bay (plankton and aquatic vegetation) and primary and secondary consumers (benthic organisms, finfish, and waterfowl) are described in general terms.

PLANKTON

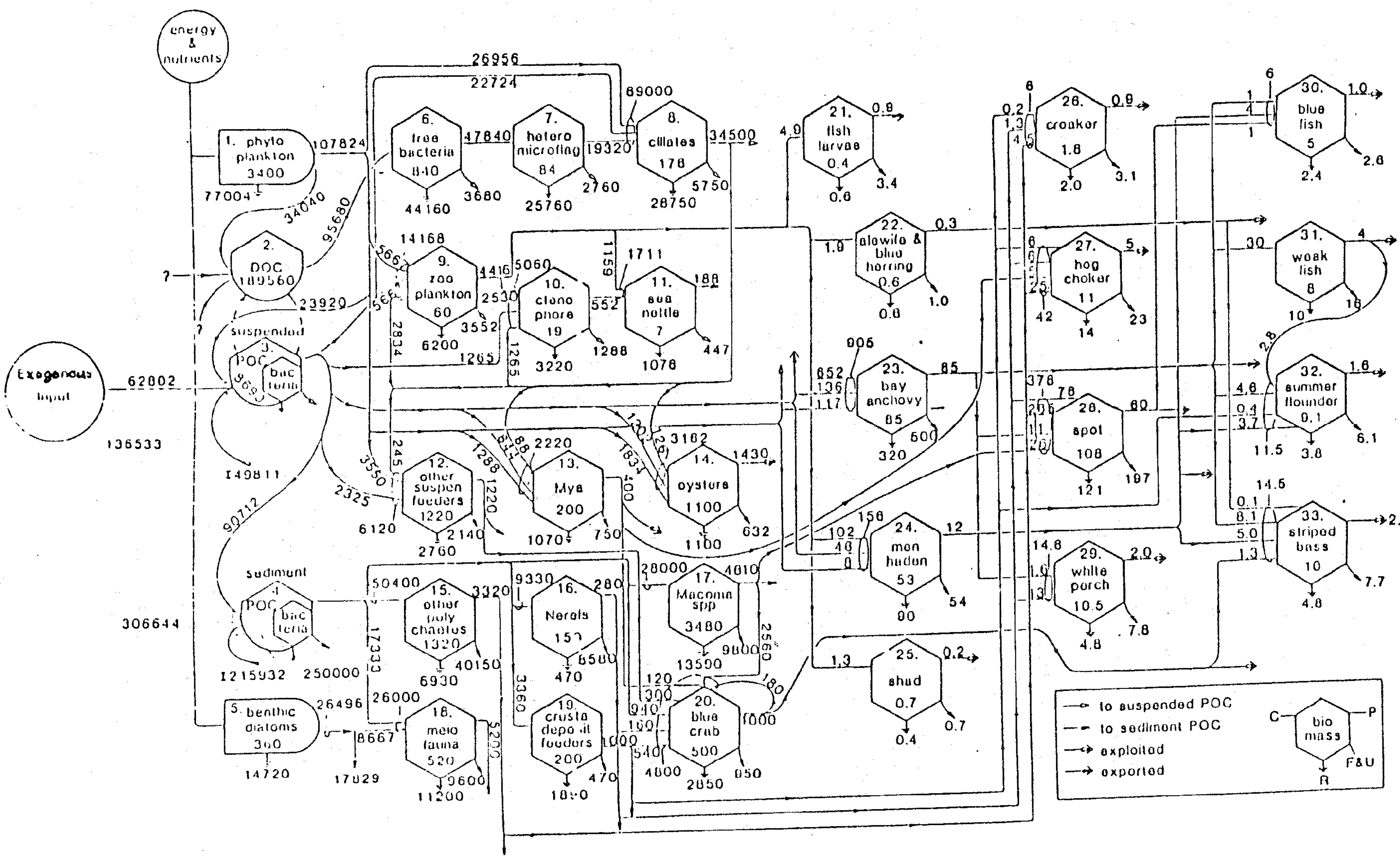
PHYTOPLANKTON AND BACTERIA

Phytoplankton are microscopic, usually single-celled plants, representing several divisions of algae. They constitute the base of the food chain; the major primary producers in Chesapeake Bay. Thus, phytoplankton play a fundamental role in the structure of the ecosystem. They are the major food source for a number of species including zooplankton, benthic suspension feeders, and fish. Bacteria are single-celled organisms that are responsible for tremendous amounts of carbon and nutrient-cycling processes (see Figure 1). As part of the detritus food chain, their role in decomposition of organic matter, particularly dead plankton cells, is a major causative factor of anoxia in bottom waters of the Bay.

In the surface waters of the Bay, dissolved nutrients and sunlight are taken up by these photosynthetic organisms. Factors which control fluctu-

FIGURE 1. Schematic Representation Of Carbon Flows Among The 33 Principal Components Of The Chesapeake Mesohaline Ecosystem During A Typical Summer. Standing Crops Are Indicated Within The Compartments In mgC m-2 And The Indicated Flows Are In mgC m-2 summer-1.

Source: Ulanowicz and Baird, 1986. " A Network Analysis of the Chesapeake Bay Ecosystem.



ations in phytoplankton numbers, composition, and production are critical to the success or failure of higher trophic levels. The balance among photosynthesis, nutrient exchange and predation ultimately determines planktonic species composition. Large changes in nutrient and toxic loadings can also cause changes in the quantity and quality (size and species composition) of plankton communities in the system. There is growing evidence that a combination of factors, probably arising from the synergistic effect of point and nonpoint source discharges of toxics and nutrients, are causing a shift in species composition. This shift is reflected in high production of bacteria and minute phytoplankton species (favoring microzooplankton production) and may be related to reduced population numbers in the higher trophic levels of the system. Oysters, for example, may grow more slowly in areas where nutrient enrichment has shifted phytoplankton species composition to smaller species which are not suitable as food.

ZOOPLANKTON

Zooplankton are swimming or floating animals that range from microscopic to jellyfish size. Many are important food for fish and other organisms. Zooplankton represent important primary consumers in the Chesapeake Bay food web, and thus function as a key link in the transfer of energy derived from phytoplankton, bacteria and detritius to higher trophic levels. Some zooplankton, particularly the mesozooplankton (medium-size), function as important and often critical links by supplying food to larval stages of many fish and shellfish species in higher trophic levels. The distribution of mesozooplankton and the phytoplankton upon which they feed is a function of salinity.

Jellyfish, including ctenophores (comb jellies) and sea nettles, prey on the smaller zooplankton and may influence summer planktonic populations and distributions. Microzooplankton, which are mostly single-celled protozoa, feed heavily on bacteria. The larvae of benthic animals and fish are also considered to be zooplankton. These larvae prey on smaller forms of plankton and may be consumed by larger animals. As the larvae develop, they may in turn consume other zooplankton.

VEGETATION

SUBMERGED AQUATIC VEGETATION

Submerged aquatic vegetation (SAV) is one of the Chesapeake Bay's most significant natural resources. In 1976, the decline of SAV was selected as one of the three major Bay problems (the only one directly focused on living resources) to be further researched. Since that time, SAV has remained at the forefront of public consciousness. It provides food and habitat for fish, numerous other aquatic organisms, and waterfowl. SAV remains a visible indicator of good water quality and the general ecological health of the Chesapeake Bay.

Several of the key species identified for detailed analysis in this effort require SAV (directly or indirectly) for food and/or habitat. Plants such as eelgrass (a common SAV species in mid to high salinity regions) and emergent marsh grasses are major sources of primary productivity in the shallow waters of the Bay. In addition to being a direct food source for some consumers, organic detritus produced by decomposition of plant material provides food for other primary consumers such as small crabs, shrimp, selected fish and other detritivores.

Associations between SAV and finfish, shellfish, and waterfowl are well documented. The most important waterfowl wintering areas have been the most abundantly vegetated. Fish abundance in SAV communities in the upper Bay is high, indicating the importance of SAV for food and shelter. Lower Bay SAV beds serve as a primary blue crab nursery, sheltering large numbers of juvenile blue crabs throughout the year.

Because prey organisms use SAV habitats, predators may be attracted to the beds. Adult fish, such as striped bass and bluefish, may hunt invertebrate prey in SAV beds. Summer resident wading and shore birds seek prey in or near SAV beds.

SAV also functions as an important stabilizer for sediments. As turbid water circulates through SAV beds, sediments tend to settle out, resulting in clearer water and increased light transmittance. Direct uptake of nitrogen and phosphorus by SAV and its associated epiphytes also serves to buffer nutrient levels in the water during the spring and summer growing season. Decomposition of SAV releases nutrients back to the water column during the fall and winter when water column nutrient concentrations are lower.

TIDAL WETLANDS

The abundance of food and shelter provided by marsh grasses ensures a very favorable habitat for other members of this community. A host of invertebrates feed on decomposed plant material and, in turn, provide food for numerous species of higher animals. Another source of food is the dense layer of bacteria, algae, and microscopic animals that coats the stems of marsh plants. Decomposing plants and, to a lesser extent, dead animals are major food sources for the marsh dwellers. Therefore, the primary food web in the marsh environment is based on detritus. Tidal marshes are also important as physical habitat for estuarine species.

Salinity and frequency of tidal flooding are the most important factors in determining the types of plant and animal populations that inhabit a particular marsh. Freshwater marsh vegetation includes cattails, reeds, arrow-arum, big cordgrass, wild rice, three-square, tearthumb and pickerel weed. Salt marshes of the mid and lower Bay are dominated by salt meadow cordgrass, saltgrass, and saltmarsh cordgrass. Irregularly flooded salt marshes have the fewest plant species and are dominated by needlerush.

Situated at the boundary between land and water, marshes absorb the erosive energy of waves and may also act as nutrient buffers, regulating the flow of local sources of nutrients into the Bay. Nutrients taken up by marsh vegetation are later slowly released into the Bay during decomposition. Marshes also protect the Bay ecosystem by trapping sediments that enter from streams or tidal flooding.

BENTHOS

The Chesapeake Bay supports an active community of organisms which live in association with bottom sediments or attached to solid substrate such as oyster shells, pilings, rocks, and shoreline structures. This assemblage, collectively known as the benthos, represents a major component of the Bay ecosystem. The benthos forms an important link between primary producers and higher trophic levels. Many benthic organisms are principal food sources for fish, waterfowl and crabs, while others are of direct economic importance (crabs, clams, oysters). Benthic organisms also play a significant role in the detrital pathway, breaking down organic matter. These decomposers are responsible for many key benthic processes, including nutrient recycling, sediment chemistry, and the depletion of dissolved oxygen.

The temporal and spatial distribution of benthic communities is determined primarily by chemical and physical factors (mainly salinity, depth, substrate, dissolved oxygen concentration, and temperature). The distribution and abundance of organisms composing benthic communities are, therefore, likely to respond to changes in water and sediment quality. Many benthic organisms live for 1-2 years or longer so that benthic communities are excellent indicators of an area's short and long-term trends in environmental quality. In addition, because benthic organisms past the larval stage are relatively immobile, they often complete much of their life cycles within well-defined regions of the Bay. As a result, benthic responses to changes in habitat quality are likely to be region-specific. As important intermediate links in the Bay's food web, benthic community responses to habitat changes are also likely to be representative of the responses of other living resources.

FINFISH

Finfish represent the majority of Chesapeake Bay nekton species. The trophic relationships of fish are diverse, depending on developmental stage, life histories, or physiological adaptations of different species. Most of the large fish species of the Bay like bluefish, striped bass, and sea trout, are temporary residents, living in the Bay for part of the year or only during certain stages of their life cycles to spawn or feed. Resident finfish, such as bay anchovies, hogchokers, and white perch, tend to be smaller in size. The spawning behaviors of Chesapeake Bay finfish place them into two main categories: ocean-spawning fish (spot, croaker, menhaden) and freshwater or estuarine-spawning fish (striped bass, herrings, shad).

Finfish occupy different trophic levels at specific stages of their lives. Most finfish initially feed on zooplankton and later turn to larger prey. The highest rates of survival of larval stages have been shown to correlate positively with the highest zooplankton densities. Thus, the success of species using the Bay as nursery grounds in its early life stages is dependent on the availability of certain types of plankton.

Finfish are represented by all consumer levels within the Bay's food web. Primary consumers, such as abundant schools of plankton-feeding menhaden, represent a major pathway from the primary producers directly to harvestable resources. Bluefish and striped bass are secondary or tertiary consumers, feeding on smaller finfish. Finfish also serve as prey for other consumer-level species. The diets of many invertebrates, waterfowl, and some mammals are composed largely of fish.

WATERFOWL AND WILDLIFE

In addition to the Chesapeake Bay's importance as a source of valuable finfish and shellfish resources, the marshes and woodlands surrounding the Bay provide habitat for a variety of waterfowl, birds and other vertebrates.

The Chesapeake Bay is part of an important migratory path known as the Atlantic flyway. Most of the waterfowl reared between the western shore of Hudson Bay and Greenland spend some time in the marshes and on the waters of the Chesapeake Bay during their migrations. The Bay and the Delmarva peninsula provide some of the prime, most heavily used waterfowl wintering habitat along the Atlantic flyway.

Like finfish, bird species occupy all consumer levels of the food web. Some birds feed on primary consumers (such as mollusks), while other species feed on primary producers (plants). Birds feeding on secondary consumers, such as fish, are considered tertiary consumers; at the extreme edge of the food web, these high-level consumers (e.g. bald eagles) are often the first to be affected by disruption of the ecological integrity of the Bay.

CHESAPEAKE BAY HABITAT ZONATION

The variety of habitats within the Chesapeake can be classified using the two most basic factors controlling the distribution of Bay biota: water depth and salinity. In this classification of Bay habitats, gradients of depth and salinity can be divided into descriptive zones. Depths range from the deepest troughs and channels in the mainstem Bay to the intertidal shores and critical land areas bordering tidal waters. Salinity ranges from the tidal freshwater stretches of Bay tributaries and upper Chesapeake to the ocean-like water at the mouth of the Bay. Within these zones, many other physical and biotic factors such as sediment type, the presence of food and cover, the strength of waves and currents, water temperature, dissolved oxygen, and habitat contamination and disturbance control the distribution and abundance of living resources. A generic system of habitat zones, defined in terms of salinity and depth, offers a simplistic way to classify, describe, monitor, and manage living resources in Chesapeake Bay.

Brief descriptions of depth and salinity zones follow, along with examples of representative species in each zone.

DEPTH ZONES

UPLAND SHORES

A variety of vegetation types exists on the upland shores which are the terrestrial communities at elevations above the influence of tides. In many cases, the physical nature of these upland regions is heavily influenced by human activities, especially development and agriculture. Several species that depend upon Bay aquatic habitats also rely upon these terrestrial environments for food, cover, or nesting sites. Examples of these species include the bald eagle, Canada goose, river otter, beaver, and mink.

INTERTIDAL AND LITTORAL

The intertidal and littoral zones include areas with water depths of approximately 0.5 meters (m) or less. They are semi-aquatic habitats, covered periodically by tidal waters or washed by waves. These zones include marshes, sandy beaches, mudflats, and shoreline structures such as revetments and bulkheads. Representative species include marsh grasses, shorebirds, waterfowl, muskrats, many benthic species, and larval or juvenile stages of finfish and crabs.

SHALLOW WATER

The shallow water zone (to a depth of < 3 m) includes the uppermost waters over the surface of the entire Bay and its tidal tributaries as well as the bottom sediments in the shallow-water areas. Examples of important resident organisms include submerged aquatic vegetation, waterfowl, shallow-water benthic species, crabs, and most juvenile finfish.

MID-WATER

The intermediate zone, with water depths between 3 and 6 m, includes the mid-layer of pelagic waters and the underlying sediments. Submerged aquatic vegetation is absent from all but the clearest waters at these depths. Oyster bars and softshell clam habitat are most common in this zone. Oyster bars support a specialized community of invertebrates, finfish and microorganisms. In the summer, finfish, crabs, and other invertebrates which would normally inhabit deeper water may be restricted to the intermediate zone by the availability of dissolved oxygen.

DEEP WATER

Deep pelagic waters of the Bay having water depths of > 6 m constitute habitat for most of the larger adult finfish. Many infaunal benthic species inhabit the underlying sediments. Seasonal depletion of dissolved oxygen in much of the Bay's deeper waters probably has limited the distribution of species that otherwise would depend on these habitats. Examples include adult striped bass, sciaenid finfish (croaker, spot, weakfish), flounder, sturgeon, and infaunal invertebrates such as *Macoma* clam.

SALINITY ZONES

The absolute geographic location of salinity zones varies greatly, influenced by freshwater discharge, tides, weather, and water depth. Each salinity zone includes the associated sediments and intertidal habitat.

TIDAL FRESH

The tidal fresh zone has salinities of < 0.5 ppt and includes the upper tidal reaches of all Bay tributaries and the area of the upper Bay known as the Susquehanna Flats. The tidal areas are critical spawning grounds for anadromous finfish, but otherwise support mostly freshwater species of finfish, invertebrates and plankton. Tidal fresh zone residents also include several species of freshwater marsh plants, submerged aquatic vegetation, as well as raptors, waterfowl, and upland wildlife.

OLIGOHALINE

The oligohaline zone, with a salinity range of 0.5 - 5.0 ppt, generally includes the middle reaches of tidal tributaries and a portion of the upper mainstem Bay, usually between the Susquehanna Flats and the mouth of the Patapsco. These areas support fresh and brackish water species of aquatic vegetation and are important nursery areas for anadromous finfish and spawning grounds for estuarine finfish. Benthic species diversity is at its lowest level in this zone, but some characteristic species (e.g. brackish-water clam (*Rangia cuneata*)) are dependent upon it and can be present in high densities. This zone is also characterized by high turbidity since it is a mixing zone of freshwater flow on the surface and the heavier, saline water along the bottom.

MESOHALINE

The mesohaline portion comprises the most extensive salinity zone in the Chesapeake Bay and has salinities ranging from 5.0 to 18 ppt. Under average rainfall conditions, this zone encompasses the mainstem Bay from the mouth of the Patapsco to the area just south of the Potomac River mouth. The lower reaches of the major tributaries in the upper Bay are also mesohaline. Most of the Chesapeake Bay species of finfish, shellfish and benthic organisms, along with euryhaline (tolerant of a wide range of salinities) marine species, inhabit this zone.

POLYHALINE

Most of the polyhaline zone, with salinity ranging from 18 to 32 ppt., is found in the Virginia portion of the mainstem Bay. The lower reaches of the York and James rivers are also in this zone. Some marine finfish live solely in this segment of the Bay, although most of the estuarine finfish species are also present. Spawning and overwintering habitat for female blue crabs occurs within the polyhaline zone near the Bay mouth. Some benthic invertebrates such as the hard clam (*Mercenaria mercenaria*), the whelk or "conch" (*Busycon* spp.), and the oyster drill (*Urosalpinx* spp.), are generally restricted to this zone. Saltmarsh grass (*Spartina* spp.), eelgrass (*Zostera* sp.), and widgeongrass (*Ruppia* sp.) are typical in the polyhaline zone.

SPECIES SELECTION

REPRESENTATIVE LIVING RESOURCES

The following list of species or species associations was developed by the Living Resources Task Force to serve as an indicator of the Bay's ecological condition. Not all species are indicators of recovery; rather, the abundance of some are reflective of poor habitat conditions for less tolerant species. The list includes species of commercial and recreational importance and species which, due to their abundance, productivity, or distribution, are important in the flow and accumulation of energy through various trophic levels of the Chesapeake Bay ecosystem.

PHYTOPLANKTON ASSOCIATIONS:

Oligohaline

Winter/Spring
Cyclotella striata
Melosira granulata
Melosira islandica
Katodinium rotundatum
Cyclotella meneghiniana
Skeletonema costatum

Summer/Fall
Cyclotella striata
Merismopedia spp.
Microcystis aeruginosa
Gymnodinium spp.
Argetoceros spp.
Skeletonema costatum

Mesohaline

Winter/Spring
Skeletonema costatum
Cyclotella striata
Heterocapsa triquetra
Certaulina pelagica
Asterionella glacialis
Asterionella japonica

Summer/Fall
Cyclotella striata
Cryptomonas spp.
Skeletonema costatum

Summer/Fall (continued)
Leptocylindrus minimus

Polyhaline

Winter/Spring
Skeletonema costatum
Leptocylindrus danicus
Asterionella glacialis
Cerataulina pelagica
Thalassiosira nordenskioldii
Thalassiosira rotula

Summer/Fall
Prorocentrum micans
Prorocentrum minimum
Heterocapsa triquetra
Cryptomonas spp.
Skeletonema costatum

ZOOPLANKTON ASSOCIATIONS:

Tidal fresh to oligohaline

Bosmina longirostris (Cladoceran)
Leptodora kindtii
Cyclops spp.
Mesocyclops edax
Diaptomus spp.
Tintinnids

Mesohaline to polyhaline

Winter
Cyanea capillata (lion's mane jellyfish)
Eurytemora affinis (copepod)
Acartia clausi (copepod)
Pseudocalanus spp.
Centropages hamatus
Temora longicornis
Neomysis americana
Sagitta elegans
Oithona spp.

Summer
Chrysaora quinquecirrha (sea nettle)
Mnemiopsis leidyi (ctenophore)
Podon polyphemoidese (cladoceran)
Evadne tergestina
Acartia tonsa (copepod)
Pseudodiaptomus coronatus
Labidocera aestiva
Parvocalanus crassirostris
Neomysis americana

Summer (continued)

Sagitta tenius
Scottolana canadenis (meiobenthic copepod)
Ectinosonia centicorne (meiobenthic copepod)

SUBMERGED AQUATIC VEGETATION SPECIES:

Ruppia maritima (widgeongrass)
Zostera marina (eelgrass)
Vallisneria americana (wild celery)
Potamogeton pectinatus (sago pondweed)
Potamogeton perfoliatus (redhead grass)

EMERGENT AQUATIC VEGETATION SPECIES:

Spartina alterniflora (salt marsh cordgrass)
Spartina cynosuroides (big cordgrass)
Spartina patens (salt meadow cordgrass)
Juncus roemerianus

BENTHIC ASSOCIATIONS:

Tidal fresh

Tubificidae (Limnodrilidae)
Chironomidae
Corbicula manilensis (Asian clam)

Oligohaline

Rangia cuneata (brackish water clam)
Scolecolepides viridis (polychaete worm)

Mesohaline

Macoma balthica (Baltic clam)
Heteromastus filiformis (polychaete worm)
Streblospio benedicti (polychaete worm)
Leptocheirus plumulosus (amphipod)
Mya arenaria (soft-shelled clam)

Polyhaline

Loimia medusa
Mulinia lateralis
Asabellides oculata
Sphiophanes bombyx
Mercenaria mercenaria (hard clam)
Maldanids
Tellinids
Nephtyiids
Phoxocephalids
Haustoriids

Euryhaline

Callinectes sapidus (blue crab)

Motile epifauna

Palaemonetes pugio (grass shrimp)
Gammarus gammarus (amphipod)
Crangon
Corophium
Mysidacea

Sessile epifauna

Balanus improvisus (barnacle)
Mytilis edulis
Molgula spp.
Bryozoa
Crassostrea virginica (American oyster)
Anemones

FINFISH SPECIES:

Freshwater and Estuarine Spawners

Alosa sapidissima (American shad)
Alosa pseudoharengus (alewife)
Alosa aestivalis (blueback herring)
Alosa mediocris (hickory shad)
Anchoa mitchilli (Bay anchovy)
Menidia menidia (Atlantic silverside)
Morone saxatilis (striped bass)
Morone americana (white perch)
Perca flavescens (yellow perch)
Acipenser oxyrynchus (Atlantic sturgeon)
Acipenser brevirostrum (shortnose sturgeon)
Fundulus heteroclitus (mummichog)
Micropterus salmoides (largemouth bass)
Pseudopleuronectes americanus (winter flounder)
Trinectes maculatus (hogchoker)
Cynoscion regalis (weakfish)
Cynoscion nebulosus (spotted seatrout)
Pogonias cromis (black drum)

Ocean Spawners

Brevoortia tyrannus (menhaden)
Leiostomus xanthurus (spot)
Micropogonias undulatus (Atlantic croaker)
Sciaenops ocellatus (red drum)
Centropristis striata (black sea bass)
Paralichthys dentatus (summer flounder)
Pomatomus saltatrix (bluefish)
Anguilla rostrata (eel)

WATERFOWL AND OTHER AQUATIC BIRD SPECIES:

Anas platyrhynchos (mallard)
Anas rubripes (black duck)
Aythya valisneria (canvasback)
Aythya americana (redhead duck)
Aix sponsa (wood duck)
Ardea herodias (great blue heron)
Florida caerulea (little blue heron)
Butorides striatus (green-backed heron)
Casmerodius albus (American egret)
Egretta thula (snowy egret)
Pandion haliaetus (osprey)
Haliaeetus leucocephalus (bald eagle)
Clangula heimalis (old squaw)
Melanitta deglandi (white-winged scoter)
Olor columbianus (tundra swan)
Megaceryle alcyon (kingfisher)
Anas acuta (northern pintail)
Anas strepera (gadwall)
Anas americana (American widgeon)
Branta canadensis (Canada goose)
Sterna albifrons (least tern)
Haematopus palliatus (oystercatcher)
Rynchops niger (black skimmer)
Limnodromus spp. (dowitcher)
Arenaria interpres (ruddy turnstone)
Actitis macularia (spotted sandpiper)

OTHER VERTEBRATE SPECIES:

Mustela vison (mink)
Lutra canadensis (river otter)
Ondatra zibethica (muskrat)
Castorcanadensis (beaver)
Caretta caretta (Atlantic loggerhead turtle)
Lepidochelys kempi (Atlantic ridley turtle)
Malaclemys terrapin (diamondback terrapin)

TARGET SPECIES

The following list of target species, selected from the list of key representative species by the Living Resources Task Force, was reviewed by participants at the Habitat Requirements Workshop held on February 24, 1987. Selection criteria are outlined in the introduction of this document. Species grouped together with the symbol "*" were determined to have habitat requirements similar enough to permit treatment as a group rather than as individuals.

SUBMERGED AQUATIC VEGETATION:

Ruppia maritima (widgeongrass)
Zostera marina (eelgrass)
Vallisneria americana (wild celery)
Potamogeton pectinatus (sago pondweed)
Potamogeton perfoliatus (redhead grass)

FINFISH:

Morone saxatilis (striped bass)

* *Alosa aestivalis* (blueback herring)
* *Alosa pseudoharengus* (alewife)

* *Alosa sapidissima* (American shad)
* *Alosa mediocris* (hickory shad)

Perca flavescens (yellow perch)
Morone americana (white perch)
Brevoortia tyrannus (menhaden)
Leiostomus xanthurus (spot)
Anchoa mitchilli (bay anchovy)

SHELLFISH:

Molluscan
* *Crassostrea virginica* (American oyster)
* *Mya arenaria* (softshell clam)
* *Mercenaria mercenaria* (hard clam)

Crustacean
Callinectes sapidus (blue crab)

WATERFOWL AND OTHER AQUATIC BIRDS:

Aythya americana (redhead duck)
Anas rubripes (black duck)
Aythya valisneria (canvasback)
Aix sponsa (wood duck)

* *Ardea herodias* (great blue heron)
* *Florida caerulea* (little blue heron)

* *Butorides striatus* (green-backed heron)
* *Casmerodius albus* (American (great) egret)
* *Egretta thula* (snowy egret)

* *Pandion haliaetus* (osprey)
* *Haliaeetus leucocephalus* (bald eagle)

HABITAT MATRICES

The Living Resources Task Force, aware of the many limitations and gaps in the available information, has summarized minimum habitat requirements for selected target species. The abundance and diversity of the Bay's living resources are affected by several variables, many of which are not fully understood. If the recovery of species which have declined in the Chesapeake Bay and the reestablishment of a more balanced ecosystem are the ultimate measures of success, the achievement of certain minimum habitat requirements for specific regions in the Chesapeake Bay is an essential first step.

The following text and matrices summarize existing information on habitat requirements for the initial list of target species. For many species, reliable in situ water quality and habitat requirements are not known and numerous data gaps exist. In all instances, the Living Resources Task Force reviewed available laboratory and field studies which evaluated the tolerance of species to individual variables such as salinity, turbidity, dissolved oxygen, and toxics. Few studies dealt with the composite effects of water quality and habitat factors on survival. These variables are closely interrelated and a change in one variable often affects the relative tolerance to other factors. Water temperature, for example, is inversely proportional to dissolved oxygen. Since rates of respiration rise with increasing water temperature, animals can tolerate lower oxygen concentrations longer at lower temperatures. Toxic substances demonstrate similar interactions. In combination, these materials can exert either synergistic or antagonistic effects and their relative toxicity is generally inversely proportional to dissolved oxygen. When such interactions could clearly be identified, they have been noted in the text or accompanying matrices.

The matrices contain information available for the sensitivities of target species to toxic substances. The sensitivities have been included in the form in which they were reported in the literature (LC50, LC0, etc.). These should not be construed as levels of toxic materials that will necessarily protect the resources. Future efforts must address the interpretation of existing toxics data in the determination of specific habitat requirements.

The following sections describe the necessary requirements for each target species.

TARGET SPECIES GROUP: Submerged aquatic vegetation complex
Critical life stage: all life stages
Critical period: April-September

Five species of submerged aquatic vegetation (SAV), with tolerances spanning the full range of salinities found in Chesapeake Bay habitats, were selected as members of the target species group. Widgeongrass (*Ruppia maritima*) and eelgrass (*Zostera marina*) are representative of both the mesohaline and polyhaline zones. Sago pondweed (*Potamogeton pectinatus*) and redhead grass (*P. perfoliatus*) are tolerant of oligohaline and mesohaline salinities. Wild celery (*Vallisneria americana*) inhabits tidal fresh and oligohaline waters.

Submerged aquatic plants are particularly appropriate as target species because of their key role in providing critical habitat for other species. An SAV bed provides cover for fish and invertebrates, food for waterfowl and reduces shore erosion and suspended sediment loads. Also, SAV is a good indicator of poor water quality due to its sensitivity to turbidity and nutrient enrichment.

Light penetration limits the depth at which SAV can survive and grow. In Chesapeake Bay, this depth is usually less than 2 m, although in less turbid water some SAV species may grow at depths of 6 m or more. Dense phytoplankton blooms and epiphytic growth, stimulated by high nutrient levels, can reduce the transmittance of light to SAV leaves. Shading reduces photosynthetic activity causing depletion of carbohydrate reserves required for growth, reproduction, and overwintering. In high salinity waters, nitrogen is generally a limiting nutrient. High nitrogen concentrations can cause phytoplankton blooms and epiphytic growth harmful to SAV. In the mesohaline zone, either nitrogen or phosphorus can limit algal growth. Levels of dissolved inorganic nitrogen greater than 0.14 mg/l and dissolved inorganic phosphorus greater than 0.01 mg/l are thought to be responsible for previous SAV declines, largely because of excessive epiphytic growth and high algal concentrations in surrounding waters (Stevenson, unpublished data).

Suspended sediment also can limit light penetration in the water column. Light attenuation coefficients (kd) for photosynthetically active radiation (400-700 nm wavelength) should not exceed 2.0/m, and total suspended solids should be less than 20 mg/l to promote reestablishment of SAV (Figure 2) (Stevenson, unpublished data) in mesohaline zones.

Substantial regrowth of SAV in the tidal fresh portion of the Potomac River has been attributed to recent reductions in phosphorus loadings from the Blue Plains sewage treatment plant. In freshwater at the head of the Bay, SAV grows well in the presence of high nitrate levels apparently because phosphate concentrations are low enough to limit phytoplankton growth. In these areas, SAV is able to obtain sufficient phosphorus from the sediments. Dense beds of some SAV species, however, can raise daytime pH levels high enough to cause chemical reactions which act to release phosphate from sediments, stimulating algal growth.

Herbicides, such as atrazine, can be harmful to SAV at concentrations in excess of 10 ug/L. Water column concentrations of this magnitude are likely to occur in localized shallow embayments directly affected by agricultural runoff.

Matrix of Habitat Requirements for
Submerged Aquatic Vegetation Complex Species
Critical life stage: All life stages
Critical Life period: April - September

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	Secchi Depth (m)	Light Intensity (uE/m-2/s-1)	KD (m-1)	Chlor. (ug/l)	DIN (1) (mg/l)	DIP (1) (mg/l)	Herbicides (ug/l)	pH
Wild celery (*Vallisneria americana*)	Silt-clay-sand	Littoral (<3m)	0-5	18-35	<20	1.0	Best at 100	[ ]	<15 (1)	<0.7-1.4	<0.01	Mortality at 12 atrazine	6-9
Sago pondweed (*Potamogeton pectinatus*)	Mud better than sand	Littoral (<3m)	0-12	15-35	<20	1.0	Best at 350	1.7-2.0	<15 (1)	<0.14	<0.01	250 diquat or paraquat controls	6-9
Redhead grass (*Potamogeton perfoliatus*)	Mud, some organics	Littoral (<3m)	2-19	15-35	<20	1.0	Best at 230	1.7-2.0	<15 (1)	<0.14	<0.01	Significantly reduced photo-synthesis at > 50	6-9
Widgeongrass (*Ruppia maritima*)	Prefers sand	Littoral (<2m)	5-60	20-26	<20	1.0	Best at 236	1.7-2.0	<15 (1)	<0.14	<0.01	[ ]	6-9
Eelgrass (*Zostera marina*)	Usually sand	Littoral (0.25-1.5m)	5-35	8-30	<15	1.25	Best at 220	[ ]	<10 (2)	[ ]	[ ]	Mortality at 100-1000 ug/l atrazine	6-9

(1) Stevenson (unpublished data)
(2) Orth and Webb (unpublished data)

TARGET SPECIES: Striped bass (*Morone saxatilis*)
Critical life stage(s): larval, juvenile
Critical life period: April to June

BACKGROUND

There have been numerous literature reviews and synopses dealing with striped bass biology (e.g. Richkus, 1986; Setzler-Hamilton, 1980; Westin and Rogers, 1978; and Hildebrand and Schroeder, 1928). The reader is referred to these publications for a more thorough account of their life history.

SPAWNING AND RANGE

Striped bass spawn during the spring in tidal fresh or brackish waters. The principal spawning and nursery areas of striped bass along the Atlantic Coast are found in the Chesapeake Bay and its tributaries (Merriman, 1941) and the Hudson and Roanoke rivers (Kaumeyer and Setzler-Hamilton, 1982).

Within the Chesapeake Bay basin, major spawning areas include: the James, Pamunkey, Mattaponi, Rappahannock, Patuxent, and Potomac rivers on the western shore; the head of the Bay with the Susquehanna Flats, Elk River, Chesapeake and Delaware (C & D) Canal; and, the Choptank and Nanticoke rivers on the Eastern Shore (Mansueti and Hollis, 1963; Speir, Personal Communication, 1987).

Spawning activity is apparently triggered by a rise in water temperature. Spawning times may vary from year to year due to annual temperature variations. In the Chesapeake Bay, 1 to 3 peaks occur during each spawning season with the major peak occurring any time during the last half of April or the first week of May (Kaumeyer and Setzler-Hamilton, 1982; Grant and Olney, 1982). Research has suggested that freshwater flow (both velocity and volume) is related to successful spawning (Kaumeyer and Setzler-Hamilton, 1982; Bayliss, 1982).

TROPHIC IMPORTANCE

Adult and copepodite copepods and cladocerans are the major food items of larval striped bass. Setzler-Hamilton et al. (1981) reported that rotifers and *Eurytemora affinis* copepodites are the dominant prey for first-feeding striped bass larvae in the Potomac River. Larval striped bass from 6 to 13 mm consume copepodites, adults of cyclopoids and other copepods. The diet of larvae $\geq$ 14 mm consists almost entirely of adult copepods (Kaumeyer and Setzler-Hamilton, 1982). Westin and Rogers (1978) provided a comprehensive list of food items for striped bass at various life stages.

TOXICITY

Of all the species examined in this report, striped bass has been studied the most with respect to its sensitivity to toxic chemicals. This section summarizes selected striped bass bioassays and highlights conflicting data.

Matrix of Habitat Requirements for
Striped bass (*Morone saxatilis*)
Critical life stage: larval, juvenile
Critical life period: April - June

Target Species	Zone	Salinity (ppt)	Temp. (C)	Metals (mg/l)	DO (mg/l)	Insecticides (ug/l)	pH	TRC (mg/l)	Flow (m/s)	Alkalinity (mg/l)	Total Hardness (mg/l)
Striped bass (*Morone saxatilis*)	Water column demersal (1)	0-5 (1)	16-19	Cadmium LC0 0.001 Copper sulfate LC0 0.10 Cupric chloride LC0 0.10 Zinc chloride LC0 0.10 Other metals of concern: Diss. Al TBT	Tolerate 4.5-20 (2) Optimum (2) 6-12	Malathion <14 Chlordane (2) <2.4 2,4,5-T <10	Optimum 7.5 - 8.5	(see text for narrative requirements)	0.3-5.0 (3)	>20 (2)	200-250
PREY SPECIES:											
Cyclops nauplii and copepodites Copepods Cladocera (sididea) Copepods: (cyclops) (Diaptomus) Cladocera (Diaphanosomal) Neomysis Gammarus Calanoida Chironomidae larvae											

(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) Fay et al. (1983)

Refer to Appendix A for more specific toxicity values.

Hall (1984) reported that water quality data from an on-site toxicity experiment on the Nanticoke River implicated that aluminum toxicity was induced by low pH. According to Richkus (1986), striped bass exhibited "no detectable effect" from aluminum concentrations of 200 to 400 ug/l at about pH 7. However, a pH of 6.5 or less with aluminum concentrations in the range of 25 to 100 ug/l caused significant mortality dependent upon the life stage of the striped bass (Richkus, 1986). O'Rear (1972) compared the relative toxicity of copper and zinc on embryos. Copper was more toxic, with a 48 hr LC50 value of 0.74 ppm. Hughes (1973) tested the tolerance of larval striped bass to cadmium, copper, and zinc. Cadmium was the most toxic. Larval striped bass experienced 50% mortality when exposed to 0.001 ppm of cadmium chloride for 96 hr (Kaumeyer and Setzler-Hamilton, 1982).

Data indicate that levels of total residual chlorine (TRC), while not necessarily lethal, may have significant sublethal effects on striped bass. For example, striped bass larvae exhibited significantly shorter body lengths after eggs were exposed to 0.15 ppm of total residual chorine. Kaumeyer and Setzler-Hamilton (1982) report that striped bass eggs exhibit 50% and 100% reduction in hatch rate when exposed to 0.19 and 0.43 ppm of TRC, respectively.

Lethal concentrations of toxic substances at various stages of the striped bass life history have been summarized by Richkus, 1986; Westin and Rogers, 1978; DiNardo et al., 1984; Emergency Striped Bass Study, 1984; and, Bonn et al., 1976.

Appendix A contains additional information on the sensitivity of striped bass for a selected group of toxic substances.

TARGET SPECIES: Alewife (*Alosa pseudoharengus*)
Critical Life Stage(s): egg, larval
Critical Life Period: Early April to mid-June

TARGET SPECIES: Blueback herring (*Alosa aestivalis*)
Critical Life Stage(s): egg, larval
Critical Life Period: Early April to end of May

BACKGROUND

This profile covers the life history and environmental requirements of the blueback herring (*Alosa aestivalis*) and the alewife (*Alosa pseudoharengus*), since their distributions overlap and their morphology, ecological roles, and environmental requirements are similar. The alewife and blueback herring are anadromous species found in riverine, estuarine, and Atlantic coastal habitats, and have occurred historically throughout the Chesapeake Bay region (Hildebrand and Schroeder, 1928). Since the early developmental stages of the blueback herring, alewife, and hickory shad (*Alosa mediocris*) are difficult to separate and the spawning seasons and locations overlap for all these species, the matrix developed for both species also is applicable to the hickory shad.

SPAWNING AND RANGE

The spawning locations and seasons of blueback herring and alewife overlap considerably. Blueback herring usually do not ascend streams as far as alewives (Hildebrand and Schroeder, 1928; Scott and Crossman, 1973). Blueback spawn in both fresh and brackish water in rivers and ponds (Davis, 1973; Hildebrand, 1963). However, Loesch and Lund (1977) reported that blueback herring preferred spawning in fast-flowing waters with hard substrates. Alewife often spawn in slower-moving waters (Wang and Kernehan, 1979). Because spawning by blueback herring is more site-specific than for alewife, dams and alteration of blueback spawning sites may be more detrimental to their population.

The spawning period for these two species is also very similar. Blueback spawning occurs from late April to early May in the Potomac River (Hildebrand, 1963). Alewives spawn from early April through mid-May (Wang and Kernehan, 1979).

Smith (1971) observed blueback spawning at water temperatures of 19-24 degrees C, but Wang and Kernehan (1979) reported slightly lower spawning temperatures (15.0-22.0 degrees C). Alewives spawn at water temperatures from 12.0-22.5 degrees C (Wang and Kernehan, 1979). Alewife eggs hatch at temperatures ranging from 12.7-26.7 degrees C (Atlantic States Marine Fisheries Commission, 1985). Klein and O'Dell (1987) report that the optimum temperature range for river herring larvae is 16-24 degrees C.

TROPHIC IMPORTANCE

The river herrings, blueback herring and alewife, are seasonally abundant fish feeding chiefly on zooplankton, particularly copepods (U.S. Corps of Engineers, 1984). The larvae for these two species consume primarily zooplankton and relatively small cladocereans and copepods (U.S. Fish and Wildlife Service, 1983). Juveniles and adults consume fish, crustacean and insect eggs, as well as adult insects; young fish may also constitute a portion of the diet when available (U.S. Corp of Engineers, 1984).

ENVIRONMENTAL CONDITIONS

The LC50 of total residual chlorine (TRC) for blueback herring eggs ranges from 0.20-0.32 ppm (U.S. Fish and Wildlife Service, 1983). Eggs exposed to 84 mg/l of TRC reached early embryo stages but failed to develop further. Larvae from eggs exposed to sublethal concentrations of total residual chlorine were all deformed. Concentrations of 36 mg/l TRC produced 100% mortality in 1-day old larvae (U.S. Fish and Wildlife Service, 1983). Ammonia, nitrites and any form of reduced nitrogen are toxic. Nitrogen and phosphorus can indirectly affect food production and induce anoxic conditions (Connery, 1987).

Auld and Schubel (1978) found that suspended sediments at concentrations of 100 ppm or less had no significant effect on the hatch rate of alewife or blueback herring eggs. Research suggests that water flow created by shear, power plant uptake, pressure drop, and dam turbines is critical to the reproduction and survival of river herrings (Connery, 1987).

Matrix of Habitat Requirements for
Alewife (*Alosa pseudoharengus*)
Critical life stage: egg, larval
Critical Life period: April to mid-June

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	pH	DO (mg/l)	Suspended Solids (mg/l)
Alewife (*Alosa pseudoharengus*)	Sand, gravel with 75% silt *critical for eggs and spawning (3)	0-5 (optimum) (1)	Eggs: 12.7-26.7 (2) Larvae: 16 - 24 (2)	<50 (2)	6.5-8.5 (2)	>5.0 (2)	50
PREY SPECIES:							
Zooplankton Cladocerans Copepods							

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) Klien and O'Dell (1987)
(3) FWS/DBS-82/11.9 October 1983

Matrix of Habitat Requirements for
Blueback herring (*Alosa aestivalis*)
Critical life stage: egg, larval
Critical Life period: early March to the end of May

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	pH	DO (mg/l)	Suspended Solids (mg/l)	TRC (mg/l)
Blueback herring (*Alosa aestivalis*)	Sand, gravel with 75% silt *critical for eggs and spawning (3)	0-5 (optimum) (1)	Eggs: 12.7-26.7 (2) Larvae: 16 - 24 (2)	<50 (2)	6.5-8.5 (2)	>5.0 (2)	<50	<0.20 (3)
PREY SPECIES:								
Zooplankton								
Cladocerans								
Copepods								

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) Klien and O'Dell (1987)
(3) FWS/DBS-82/11.9 October 1983

TARGET SPECIES: American shad (*Alosa sapidissima*)
Critical Life Stage(s): egg, larval
Critical Life Period: Mid-April to early June

TARGET SPECIES: Hickory shad (*Alosa mediocris*)
Critical Life Life Stage(s): egg, larval
Critical Life Period: April to June

BACKGROUND

Historically, shad have inhabited virtually all rivers feeding the Chesapeake Bay (Kaumeyer and Setzler-Hamilton, 1982). Currently, shad population numbers are extremely low in Maryland waters, and shad fishing is banned (Jones et al., 1978; Kaumeyer and Setzler-Hamilton, 1982). There is still a commercial shad fishery in Virginia tributaries, however.

SPAWNING AND RANGE

Spawning runs may begin as early as February, but are most frequent in April. Characteristic spawning and nursery grounds for shad are tidal freshwaters in estuaries and rivers; however, some shad can tolerate moderate salinities (Stagg, 1985; Kaumeyer and Setzler-Hamilton, 1982). Successful hatches have been reported at salinities ranging from 7.5 ppt at 12.0 degrees C to 15 ppt at 17 degrees C. No eggs hatched at a salinity of 22.5 ppt (U.S. Fish and Wildlife Service, 1986).

Shad spawning areas vary in depth and substrate. Shad seem to prefer areas dominated by shallow water or broad flats with sand or gravel bottoms (U.S. Fish and Wildlife Service, 1986). Sufficient water current velocities are required to keep the shad eggs suspended in the water column. Preferred velocities in spawning waters range from 30.5 to 91.4 cm/sec (U.S. Fish and Wildlife Service, 1986). Exposure of the eggs to suspended sediment concentrations as high as 1,000 mg/l did not affect hatching success (Auld and Schubel, 1978), but larval mortality was high at suspended sediment concentrations greater than 100 mg/l for 96 hours (U.S. Fish and Wildlife Service, 1986).

ENVIRONMENTAL CONDITIONS

Eggs hatch in 12 to 45 days at 12 degrees C and in 6 to 8 days at 17 degrees C (Bigelow and Schroeder, 1953). Maximum survival of eggs and larvae occurs at 15.5-26.6 degrees C (U.S. Fish and Wildlife Service, 1986). Temperatures of 7-9 degrees C were reported to be lethal to eggs and larvae and temperatures of 20.0-23.4 degrees C caused extensive larval abnormalities (U.S. Fish and Wildlife Service, 1986). The LD50 for acid pH was 5.5 and it was 9.5 for basic pH (U.S. Fish and Wildlife Service, 1986). Larval shad LD50 for low dissolved oxygen (DO) ranges from 2.0-3.5 ppm, depending on the population. Mortality of eggs was 100% at DO levels below 1.0 mg/l (U.S. Fish and Wildlife Service, 1986). Larvae exhibit significant signs of stress when exposed to a DO level of 3.0 mg/l, and many died at 2.0 mg/l (Chittenden, 1969). A DO level of > 5.0 ppm is considered optimum (Chittenden, 1969; Wang and Kernehan, 1979).

Matrix of Habitat Requirements for
American shad (*Alosa sapidissima*)
Critical life stage: egg, larval
Critical Life period: mid-April to early June

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	pH	DO (mg/l)	Suspended Solids (mg/l)
American shad (*Alosa sapidissima*)	[ ]	Egg: 7.5-15.0 at 12-17 C (3)	Egg: 15.5-26.6	<50 (2)	6.5-8.5 (2)	>5 (2)	<50
		Larvae: 0-5 (1)	Larvae: 15.5-26 (3) 16-25 (2) (See text for narrative requirements)				
PREY SPECIES: (3)							
Midge larvae Midge pupae Cyclopoid copepods *Daphnia pulex*							

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) Klien and O'Dell (1987)
(3) FWS habitat suitability index publications Biological Report 82(11.45) 1986

Matrix of Habitat Requirements for
Hickory shad (*Alosa mediocris*)
Critical life stage: egg, larval
Critical Life period: April to June

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	pH	DO (mg/l)	Suspended Solids (mg/l)
Hickory shad (*Alosa mediocris*)	[ ]	Egg: 7.5-15.0 at 12-17 C (3)	Egg: 15.5-26.6	<50 (2)	6.5-8.5 (2)	>5 (2)	<50
		Larvae: 0-5 (1)	Larvae: 15.5-26 (3) 16-25 (2) (See text for narrative requirements)				
PREY SPECIES: (3)							
Midge larvae							
Midge pupae							
Cyclopoid copepods							
Daphnia pulex							

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) Klien and O'Dell (1987)
(3) FWS habitat suitability index publications Biological Report 82(11.45) 1986

Larvae remain near the spawning grounds, usually a short distance downstream. Young remain in the nursery area until water temperatures begin to decrease in the fall. The downstream migration begins at a water temperature of approximately 21.1 degrees C (Wang and Kernehan, 1979). All young have left the nursery grounds by the time the temperature reaches 8.3 degrees C (Wang and Kernehan, 1979).

TROPHIC IMPORTANCE

Shad larvae consume cyclopoid copepods, midge larvae, midge pupae, and *Daphnia pulex* (U.S. Fish and Wildlife, 1986).

ADDITIONAL INFORMATION

For a concise overview see Boreman (1981); for a detailed study of the life history of shad see Mansueti and Kolb (1953). Reports by Cooper (1984), Richkus and DiNardo (1984), and Davis (1973) respectively provide thorough reviews on the status of Atlantic coast shad, all anadromous alosids of the eastern United States, and shad life history information for Virginia waters.

TARGET SPECIES: Yellow perch (*Perca flavescens*)
Critical life stage: egg, larval
Critical life period: first year of life

SPAWNING AND RANGE

Yellow perch make vertical temperature-dependent migrations and in-shore, upstream spawning migrations. The spawning period lasts from March to April in shallow tidal and non-tidal freshwater. Spawning occurs in low velocity currents (< 5 cm/s). The species is common where debris or vegetation are present. Eggs are gelatinous and semibuoyant (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1983; and, Wang and Kernehan, 1979). In the Chesapeake Bay, yellow perch habitat is situated between the up-stream limit of tidal freshwater to mid-mesohaline salinity zones. Spawning activity has been reported in low salinity waters up to 2.5 ppt in the Severn River (Wang and Kernehan, 1979). Hildebrand and Schroeder (1982) observed yellow perch from Havre de Grace, Maryland to Lewisetta, Virginia. The fish tend to migrate toward the shorezone in summer and into deeper waters in winter (U.S. Corps of Engineers, 1984).

TROPHIC IMPORTANCE

The principal foods of young yellow perch in freshwater consists of insects and small crustaceans (U.S. Corps of Engineers, 1984). Adults feed on soft-bodied fish, minnows, and anchovies, as well as isopods, amphipods, shrimp, crabs, insect larvae, and snails (U.S. Corps of Engineers, 1984; Hildebrand and Schroeder, 1928).

Matrix of Habitat Requirements for
Yellow perch (*Perca flavescens*)
Critical life stage: egg, larval
Critical Life period: first year of life

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	DO (mg/l)	Flow (cm/s)	pH	Cover	Suspended Solids (mg/l)
Yellow perch (*Perca flavescens*)	Egg: sand or sand & gravel mixture Larvae; silt dominant, backwater and marsh areas (3)	Demersal (see text for narrative requirement) (3)	Tolerate 0.5 (1) Optimum 16-19 (1)	Tolerate 10-19	<50 (2)	>5L (2)	Larvae (<9.5mm) unable to maintain position in current velocity) >2.5 (3)	6.5-8.5 (2)	Vegetation, submerged trees, SAV (3)	>500, reduced larval survival (1)
PREY SPECIES: Copepod nauplii Cyclopoid copepods Cladocerans Diaphanosoma										

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) Klein and O'Dell (1987)
(3) U.S. Fish and Wildlife Service (FWS/DBS-82/10.55 1983)

OTHER SENSITIVITIES

Yellow perch inhabit slow-flowing tidal rivers containing vegetation, submerged trees or pilings. Data suggest that yellow perch abundance decreases with increasing turbidity (U.S. Fish and Wildlife Service, 1983). They are able to tolerate low dissolved oxygen levels and remain active even under winter ice. However, laboratory and field studies determined that dissolved oxygen levels from 0.2-1.5 mg/l are lethal to yellow perch. A dissolved oxygen level of 5 mg/l was determined as the optimum lower limit (U.S. Fish and Wildlife Service, 1983).

TARGET SPECIES: White perch (*Morone americana*)
Critical life stage(s): egg, larval
Critical life period: first year of life

BACKGROUND

White perch are found throughout the Chesapeake Bay and C&D Canal and have been reported in marine waters north of Chesapeake Bay. White perch are considered anadromous, but non-migratory resident populations do occur.

SPAWNING AND RANGE

White perch move upriver in the spring into the shorezone of tidal fresh waters to spawn (U.S. Corps of Engineers, 1984). In the Chesapeake Bay, spawning occurs from April to June. Spawning has been observed in December when appropriate climatic conditions occurred (Hildebrand and Schroeder, 1928). The species prefers spawning over shoal hard bottoms (e.g. sand or gravel) with currents. During their first year, juveniles remain in soft-bottomed, shallow, freshwater nursery areas, preferably in vegetated zones. Juveniles larger than 25 mm in total length begin inshore-offshore movements in response to light levels. Low temperatures cause white perch to move into deeper waters. Wintering populations are found in the deeper channels and holes in the upper Bay and tributaries. White perch in the Bay system are thought to consist of isolated subpopulations indigenous to each tributary.

Adult white perch are found in salinity zones of 5-18 ppt; however, they prefer to spawn at salinities less than 4.2 ppt (U.S. Fish and Wildlife Service, 1983; U.S. Corps of Engineers, 1984). Osmotic regulation is disrupted in eggs deposited in water of salinities $\geq$ 10 ppt. Larvae can tolerate salinities in the range of 0-8 ppt (U.S. Fish and Wildlife Service, 1983).

TROPHIC IMPORTANCE

The white perch is a generalized feeder and is benthophagus or piscivorous depending upon food availability, age and season (U.S. Fish and Wildlife Service, 1983). Larvae prey upon zooplankton. Fish, crustaceans, annelids and insect larvae are taken during juvenile and adult stages (Hildebrand and Schroeder, 1928). The fry are consumed by larger prey fish such as bluefish

Matrix of Habitat Requirements for
White perch (*Morone americana*)
Critical life stage: egg, larval
Critical Life period: first year of life

Target Species	Substrate	Salinity (ppt)	Temp (C)	pH	DO (mg/l)	Turbidity (NTU)	Suspended Solids (mg/l)	Zone
White Perch (*Morone americana*)	Compact silt, sand, mud, clay (2)	Tolerate 0-8 Optimum 0-1.5	Tolerate 11-30 Optimum 12-20	6.5 - 8.5 (4)	>5 (4)	<50 (4)	<70 (4)	Subsurface waters (3)
PREY SPECIES:								
Rotifers								
Copepod nauplii								
Cladoceran:								
Bosmina								
E. affinis								
Cyclopid copepods								
Daphnia								

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) FWS/DBS-82/11.7 1983
(3) Wang and Kernehan (1979)
(4) Klien and O'Dell (1987)

(Cont'd)
Matrix of Habitat Requirements for
White Perch (*Morone americana*)
Critical life stage: egg, larval
Critical life period: first year of life

Target Species	Insecticides (mg/l)	TRC (mg/l)	Herbicides (mg/l)	Metals (mg/l)
White Perch (*Morone americana*)	DDT LC50 - 8.00 Dieldrin LC50 - 10.0	LC5 0.15 (1)	2,4-D LC50 55.5 (1)	Cupric chloride LC5 0.023 Mercuric chloride LC5 0.004 Nickel chloride LC5 0.037 Silver nitrate LC5 0.017 (1)
PREY SPECIES:				
Rotifers Copepod nauplii Cladoceran: Bosmina *E. affinis* Cyclopid copepods *Daphnia*				

(1) Kaumeyer and Setzler-Hamilton (1982)
(2) FWS/DBS-82/11.7 1983
(3) Wang and Kernehan (1979)
(4) Klien and O'Dell (1987)

and striped bass (Hildebrand and Schroeder, 1928; U.S. Fish and Wildlife Service, 1983; U.S. Corps of Engineers, 1984).

TARGET SPECIES: Menhaden (*Brevoortia tyrannus*)
Critical life stage(s): juvenile
Critical life period: April to October

SPAWNING AND RANGE

Juvenile menhaden are found in upper Chesapeake Bay tributaries from late May through November. Kaumeyer and Setzler-Hamilton (1982) report that juveniles were found in the Potomac River in March and April and in the upper Bay from late May through late June and in November. April through October is generally the peak time of abundance in the upper Chesapeake Bay. During the post-larval stage, menhaden tend to accumulate at the fresh/salt-water interface in the upper Bay region. Juveniles in the upper Bay begin to emigrate, generally after their first summer, from the freshwater interface into the mesohaline zone (U.S. Corps of Engineers, 1984; Kaumeyer and Setzler-Hamilton, 1982). Larger fish are found in the deeper waters down the Bay. Sub-adults leave the estuary with the adults in October; however, some over-wintering occurs in Chesapeake Bay (U.S. Corps of Engineers, 1984; Kaumeyer and Setzler-Hamilton, 1982).

Spawning and early larval development occur in continental shelf waters of the Atlantic. Menhaden are estuarine dependent, utilizing the estuary both as a nursery for juveniles and as adult feeding ground during the summer months (Bigelow and Schroeder, 1953; Reintjes, 1969; and U.S. Corps of Engineers, 1984). Reintjes (1969) observed eggs and small larvae in Long Island Sound, Narragansett Bay, and Chesapeake Bay, but suggested that spawning in these areas made minor contributions to total population numbers.

TROPHIC IMPORTANCE

Menhaden represent a major energy link between plankton directly to the large piscivores. Where menhaden are present in dense schools, their filter-feeding can be a primary control over local plankton abundance. According to Ulanowicz and Baird (1986), the summer diet of menhaden in the mesohaline part of Chesapeake Bay consists of zooplankton (65%), phytoplankton (5%), and unspecified organic particulates (29%).

TARGET SPECIES: Spot (*Leiostomus xanthurus*)
Critical life stage(s): juvenile
Critical life period: Early April to early November

SPAWNING AND RANGE

The spot is a demersal, marine spawning fish. Spawning activity on the continental shelf adjacent to the Chesapeake Bay was reported to occur during late fall and winter (Kaumeyer and Setzler-Hamilton, 1982). Some adults may

Matrix of Habitat Requirements for
Menhaden (*Brevoortia tyrannus*)
Critical life stage: juvenile
Critical Life period: April to October

Target Species	Zone	Salinity (ppt)	Temp. (C)	pH	DO (mg/l)	Pathogens
Menhaden (*Brevoortia tyrannus*)	Pelagic or open water	tolerate 0-34 optimum 0-15 (2)	10-30 (4)	6.5-8.5 (3,4)	>5 (3,4)	Fungal parasites
PREY SPECIES: (1)						
Phytoplankton Zooplankton Particulate organic material						

(1) Ulanowicz and Baird (1986)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) Klein and O'Dell (1987)
(4) U.S. Corps of Engineers (1984)

Matrix of Habitat Requirements for
Spot (*Leiostomus xanthurus*)
Critical life stage: juvenile
Critical Life period: early April to early November

Target Species	Substrate	Salinity (ppt)	Temp. (C)	Turbidity (NTU)	pH	DO (mg/l)	Suspended Solids (mg/l)
Spot (*Leiostomus xanthurus*)	Bottoms dominated by grasses and filter-feeding clams (4)	Tolerate 0-32 optimum 0-5 (2)	Tolerate 6.3-32.5 (2)	<50 (3)	6.5 - 8.5 (3)	>5 (3)	<70 (3)

PREY SPECIES: (1)

Nerels spp.
Other polychaetes
Macoma spp.
Ostracods
Copepods

(1) U.S. Fish and Wildlife Service (FWS/DBS-82/11.3 (1983)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) Klien and O'Dell (1987)
(4) Wang and Kernehan (1979)

spawn twice a year (U.S. Fish and Wildlife Service, 1982). Kaumeyer and Setzler-Hamilton (1982) suggested that adult spot do not survive after they spawn.

Post-larval and juvenile spot spend much of their lives in estuaries (U.S. Fish and Wildlife Service, 1982). Post-larval spot inhabit Chesapeake Bay from early April through early November (Hildebrand and Schroeder, 1928). In the Maryland portion of the Bay, spot larvae and young juveniles congregate in the oligohaline zone, although when population densities are high, some young move into tidal freshwater, shallow marshes, and drainage ditches (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1982). In the lower Bay, spot larvae and young juveniles are found in mesohaline and polyhaline tidal marshes. Spot are common near grass beds and over muddy substrates (U.S. Fish and Wildlife Service, 1982). In Chesapeake Bay, adults are found in mesohaline to polyhaline salinity zones (U.S. Corps of Engineers, 1984; U.S. Fish and Wildlife Service, 1982). Spot leave the Bay as water temperatures decline in the fall (Wang and Kernehan, 1979).

Fish in their second or third year of life do not penetrate very far into the estuary, and are abundant only in the lower Virginia portion of the Bay (U.S. Corps of Engineers, 1984). Adult spot habitat in the Chesapeake is defined as mid-mesohaline to polyhaline areas with depths to 6 m overlying soft sediment bottoms (U.S. Corps of Engineers, 1984).

TROPHIC IMPORTANCE

Juvenile spot primarily consume benthic invertebrates including: ostracods, copepods, and polychaetes (U.S. Fish and Wildlife Service, 1982). Approximately 93% of the summer diet consists of polychaetes; most of the remainder is *Macoma* spp. (Ulanowicz and Baird, 1986). Spot are preyed upon by large gamefish and also harvested by sport and commercial fisheries. Spot represent a significant link in the transfer of energy from the detritivores and primary consumers eaten by spot in the Bay to its predators in the waters of the adjacent continental shelf (U.S. Corps of Engineers, 1984).

TARGET SPECIES: Bay anchovy (*Anchoa mitchilli*)
Critical life stage(s): larval
Critical life period: May to September

BACKGROUND

Bay anchovy has been observed in virtually all open waters throughout the Chesapeake Bay from the tidal fresh to the polyhaline zone; the C & D Canal and Havre de Grace down to Lynnhaven Roads, Virginia (Wang and Kernehan, 1979; Hildebrand and Schroeder, 1928). Anchovy larvae are pelagic and are also found over a wide salinity range (Wang and Kernehan, 1979; Hildebrand and Schroeder, 1928). According to Wang and Kernehan, (1979) the larvae move upstream to low salinity regions after hatching, with the highest concentrations of larvae observed at salinities of 0-7 ppt salinity. The U.S. Corps of Engineers (1984) reported larvae at salinities of 3-7 ppt. Larvae were found 40 miles above brackish water in Virginia (Wang and Kernehan, 1979) and in the Potomac River in freshwater near Bryans Point, about 12 miles below Wash-

Matrix of Habitat Requirements for
Bay anchovy (*Anchoa mitchilli*)
Critical life stage: larval
Critical Life period: May to September

Target Species	Zone	Salinity (ppt)	Temp. (C)
Bay anchovy (*Anchoa mitchilli*)	Pelagic	0-7	15.0-30.0
PREY SPECIES:			
Copepods			
	Wang and Kernehan (1979)		

ington, D.C. (Hildebrand and Schroeder, 1928). Anchovy larvae also occur in large numbers throughout the lower Chesapeake Bay (Olney, 1983).

SPAWNING AND RANGE

The Bay anchovy spawning season occurs from May to September in the Chesapeake Bay (Wang and Kernehan, 1979). Spawning is pelagic and occurs in the Chesapeake Bay at salinities ranging from 1-22 ppt (U.S. Corps of Engineers, 1984; Wang and Kernehan, 1979). Spawning also occurs at the Chesapeake Bay mouth where salinities are typically 25-28 ppt (Olney, 1983). Wang and Kernehan (1979) reported that spawning activity in the Delaware Bay occurs between 15 degrees C and 30 degrees C with peak activity occurring at 22-27 degrees C. They also reported peak egg densities occur at salinities of 12-13 ppt in Chesapeake Bay. In the upper Chesapeake Bay, larvae are observed in shallow shore areas where the salinities range between 3-7 ppt (U.S. Corps of Engineers, 1979).

TROPHIC IMPORTANCE

Anchovies feed primarily on mysids and copepods (Hildebrand and Schroeder, 1928). In overlapping ranges, Bay anchovy larvae are reported to compete with alosid larvae for copepods (U.S. Corps of Engineers, 1984; Hildebrand and Schroeder, 1928). The anchovy is a year-round resident, and an important forage fish of the Chesapeake (U.S. Corps of Engineers, 1984). During the summer, in the mesohaline portion of Chesapeake Bay, anchovies consume large quantities of phytoplankton (13%), zooplankton (72%), and organic detritus (15%) (Ulanowicz and Baird, 1986).

ADDITIONAL INFORMATION

The larval stage is considered the most sensitive life stage for the Bay anchovy. The larvae have been observed to congregate at the surface waters of the oligohaline zone. Crowding has been observed as anchovies move into the narrower oligohaline areas of tributaries. Concentration of larvae in the surface waters may cause localized overpopulation which possibly resulting in a reduction in year class abundance (U.S. Corps of Engineers, 1984).

TARGET SPECIES GROUP: Molluscan Shellfish

American oyster (*Crassostrea virginica)*
Critical life stage(s): larval, spat and adult
Critical life period: entire life cycle

Soft clam (*Mya arenaria)*
Critical life stage(s): larval
Critical life period: May - October

Hard clam (*Mercenaria mercenaria*)
Critical life stage(s): egg and larval
Critical life period: first year of life

BACKGROUND

American oysters, soft clams, and hard clams are prominent members of the benthic community in Chesapeake Bay and contribute substantially to the economy of the region. Oysters have recently experienced severe declines in abundance. Soft clams in the Chesapeake Bay have also decreased in abundance in recent years in the Bay. Intense fishing pressure, loss of habitat, and water quality degradation have been blamed for declines in the abundance of these species. Hard clams, however, have maintained more stability in population numbers, primarily due to greater market demand for surf clams and ocean quahogs in the mid-Atlantic region.

SPAWNING AND RANGE

All Chesapeake oysters are subtidal, whereas their southern counterparts are often intertidal. American oysters prefer a firm substrate: pilings, hard rock bottoms, and substrates firmed with the oyster shells of previous generations. Soft clams in the Chesapeake inhabit shallow subtidal (10 m) estuarine waters to intertidal areas in the oligohaline through the polyhaline zones. Hard clams are euryhaline marine species sensitive to salinities below 12 ppt, and thus are only found in the lower Bay from the mesohaline through the polyhaline zone (12-32 ppt). Although found in a variety of substrates including mud, hard clams prefer a firm bottom. They favor a mixture containing sand or shell which provides points of attachment for juveniles as well as protection from many predators.

The American oyster in the Chesapeake Bay spawns in the summer when water temperatures exceed 15 degrees C. Heavy spawning is likely to occur at 22-23 degrees C. Sperm and eggs are released into the water where fertilization occurs, producing free-swimming larvae. The duration of the larval stage varies with temperature, lasting sometimes as few as 7 to 10 days, but most often between 2 to 3 weeks before the larvae set and became sessile organisms. Soft clams and hard clams, like most other bivalve mollusks, spawn when a critical temperature occurs. In the Chesapeake, soft clams spawn in the spring when water temperature reaches 10 degrees C and spawning may be repeated in the fall when water temperature falls to 20 degrees C. Soft clam eggs develop into planktonic trochophore larvae in about 12 hours. Larvae remain in the water column for about 6 weeks during the fall. The faster spring rate of larval development is caused by temperatures at the warmer end of the soft clam's spawning temperature range. Setting of soft clams, therefore, may occur twice in the same year. Frequently, however, heavy predation on the spring set by blue crabs and bottom-feeding fish results in unsuccessful recruitment. Hard clams spawn at temperatures of 22-24 degrees C. Normal egg development occurs between 20-35 ppt salinity. At salinities below 17.5 ppt, larvae fail to metamorphose and growth of juveniles ceases. Optimal temperatures for larval growth range between 18 and 30 degrees C. Growth ceases at oxygen concentrations below 2.4 mg/l.

TROPHIC IMPORTANCE

The American oyster is an epibenthic suspension feeder, ingesting a variety of algae, bacteria, and small detrital particles, most within a range of 3-35 um. Capture efficiency decreases rapidly at particle sizes < 3 um. Particles filtered but not ingested by the oyster are eliminated as pseudofeces. Fecal and pseudofecal material is important in sediment production and deposition, providing sites for remineralizing bacterial action, and as a food source for deposit feeders. The hard shell provides a substrate for numerous epifaunal organisms such as barnacles and mussels. These characteristics make the oyster an important member of the benthic community throughout the Chesapeake Bay. Oysters, especially in the juvenile stages, are subject to heavy parasitism and predation by many organisms include protozoans, crabs, snails, and flatworms.

Both soft and hard clams are also important benthic species in the Bay. Both species are infaunal suspension feeders, ingesting small detrital particles and phytoplankton, as well as bacteria and microzooplankton in the case of *Mya* spp. Adult soft clams burrow deeply, feeding through a long extensible siphon. Juveniles, burrowing less deeply, often fall prey to finfish, blue crabs and waterfowl. Commercial harvesting of adults reduces adult populations and exposes juveniles to predation before they can burrow back into the sediment. Hard clams favor shallow burrows and are also preyed upon by fish, crabs, and waterfowl, particularly during the juvenile stage. Also of commercial importance, the hard clam populations in the Bay suffer from irregular recruitment and are strictly limited to higher salinity regions.

OTHER SENSITIVITIES

Oysters are sensitive to both turbidity and sedimentation. Excessive sediment deposition smothers adults and prevents setting of spat. The observation that the upstream limit of producing oyster bars has shifted downstream several miles in historic times is evidence of the impact of sedimentation. Adult feeding rates are depressed at suspended solids concentrations above 24 mg/l and feeding ceases at concentrations above approximately 50 mg/l. Soft clams are vulnerable to sediment disturbances since they are slow reburrowers. As such, they are impacted by harvesting practices, waves, currents and bioturbation. Regrowth of SAV would benefit these bivalves by reducing the amount of sediment resuspension and the resulting turbidity.

Areas of good circulation produce better setting and survival of young oysters. Most oysters in the Chesapeake are found in areas less than 10 m deep in which circulation patterns promote adequate levels of dissolved oxygen. Soft clams are also impacted by anoxia which restricts their distribution to shallow waters less than 10 m in depth.

Oyster diseases, notably *Haplosporidium nelsoni* ("MSX") and *Perkinsus marinus* ("dermo"), have caused significant mortality in the lower Bay. The organisms causing these diseases require the higher salinities of the lower Bay to proliferate. The devastating oyster diseases, MSX and dermo, may not be restricted by salinity. Infection rate may be related to the oyster's cellular responses to salinity. In the Choptank River, at salinities < 13 ppt, MSX has been observed.

Temperatures of 32.5 degrees C or greater are lethal to adult soft clam limiting intertidal distribution in the species' southern range. For oysters, soft clams, and hard clams, it is generally agreed that food availability is another significant factor dictating their survival. Foods of critical sizes are needed for the different life stages; with the cell sizes generally ranging from 3-35 um.

Matrix of Habitat Requirements for
American oyster (*Crassostrea virginica*)
Critical life stage: larval, spat, adult
Critical Life period: entire life cycle

Target Species	Substrate	Zone	pH	DO (mg/l)	Suspended Solids (mg/l)	Salinity (ppt)
American oyster (*Crassostrea virginica*)	Firm substrate, pilings, hard rock bottom, shells (1)	Subtidal (1)	6.8-8.5 (2)	>2.4 (2)*	<35 (adult activity reduced above 24) (3)	5-35
PREY SPECIES:						
Phytoplankton size range: 3-35 microns						

(1) U.S. Fish and Wildlife Service Biological Report 82(11.65)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) Jordan (1987)

*Critical DO should be higher when temperature exceeds 25 degrees C. Exact requirements not known.

Matrix of Habitat Requirements for
Softshell Clam (*Mya arenaria*)
Critical life stage: larval
Critical Life period: May to October

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Alkalinity (mg/l)	DO (mg/l)	pH	TRC (mg/l)	Herbicides (ug/l)	Metals (mg/l)
Softshell clam (*Mya arenaria*)	Sand, sand-mud, sand-clay (2)	Shallow intertidal and sub-tidal (2)	>10.5 (1)	Mean temps during larval setting are: Spring=19.4-21.9 Fall=19.6-13.9 (2)	20 (3)	>5 (1)	6.5-8	LC0 0.05	Chlordane <2.4 (2)	LC50's for 168-hr Cu, .035 Cd, .150 Zn, 1.55 Pb, 8.80 Mn, 3.00 Ni, 50.00 (3)
PREY SPECIES:										
Microzooplankton Phytoplankton										

(1) FWS Habitat Suitability Index Publications Biological Report 82(11.68) 1986
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) EPA Quality Criteria for Water 1986

Matrix of Habitat Requirements for
Blue crab (*Callinectes sapidus*)
Critical life stage: larval, premolt, post-molt
Critical Life period: June - October

Target Species	Zone (C)	Salinity (ppt)	Temp. (mg/l)	DO (mg/l)	Flow (cm/s)	pH	Cover
Blue crab (*Callinectes sapidus*)	Euryhaline	2-21	<33	>2	See text	6-8	SAV

PREY SPECIES:

Live and dead fish
Aquatic plants
Crabs
Shrimp
Mollusks
Organic detritus
Copepods
Mysids

environmental stress during these periods. The crabs reach adult size (130 mm or larger) while on the "nursery grounds," brackish water habitats in the tributaries and mainstem of the Bay.

TROPHIC IMPORTANCE

Blue crabs are generally considered omnivorous. The zoeae and megalopae prey primarily upon zooplankton. The megalopae will also feed upon pieces of fish or shellfish and aquatic plants (Van Engel, 1958). Juvenile and adult blue crabs are also omnivorous, feeding on benthic macroinvertebrates, small fish, aquatic vegetation and associated fauna, and dead organisms (Lippson et al., 1979). The blue crab is known to prey on young quahogs and seed oysters under experimental conditions. It will also prey on oyster spat, newly set oysters and clams, or young oysters if other food is unavailable (Van Engel, 1958; Shea et al., 1980). It follows that the blue crab may be a major factor in the control of benthic populations (Shea et al., 1980).

TARGET SPECIES: Canvasback (*Aythya valisineria*)
Critical Life Stage: nestling
Critical Life Period: March - June

BACKGROUND

The canvasback is a diving duck, often descending several meters in search of food. It breeds on the North American prairies and migrates only when water becomes too cold in its summer range. Chesapeake Bay populations have been reduced from a peak of almost 400,000 canvasbacks, to averages of 250,000 in the 1950s and generally less than 70,000 in the 1980s. Before hunting reforms in 1918, canvasbacks, an international delicacy, were slaughtered in the thousands by market hunters.

Canvasbacks have adapted with success from their earlier dependence on and preference for wild celery and other submerged aquatic vegetation. These ducks now depend on *Rangia* and *Macoma* clams, snails, insects, worms and small crustaceans as a substantial portion of their diet. This dietary change has made them less desirable table fare, but canvasbacks are still much prized by hunters.

TARGET SPECIES: Redhead duck (*Aythya americana*)
Critical Life Stage: nestling
Critical Life Period: March - June

BACKGROUND

The redhead's principal breeding grounds are the North American prairies, where habitats have been reduced. Most redheads migrate to the Gulf of Mexico coast, but in the 1950s as many as 118,800 were estimated in the Chesapeake Bay during January 1956. The 1980s populations have averaged about 3,500. This duck's exceptionally large salt glands enable it to spend much

Matrix of Habitat Requirements for
Canvasback (*Aythya valisneria*)
Critical life stage: wintering
Critical Life period: November - March

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (mg/l)	Secchi Depth (m)	Light Intensity (uE/m-2/S-1)	KD (m-1) (1)
Canvasback Duck (*Aythya valisneria*)	N.L.	N.L.	N.L.	N.L.	N.L	[ ]	N.L.	N.L.
PREY SPECIES:								
Wild celery (*Vallisneria americana*)	Silt-clay sand	Littoral (3m)	0 - 5	18 - 35	<20	1.0	Best at 100	[ ]
Sago pondweed (*Potamogeton pectinatus*)	Mud better than sand	Littoral (3m)	0 - 12	15 - 35	<20	1.0	Best at 350	1.7 - 2.0
Redhead grass (*Potamogeton perfoliatus*)	Mud, some organics	Littoral (3m)	2 - 19	15 - 35	<20	1.0	Best at 230	1.7 - 2.0
Widgeongrass (*Ruppia maritima*)	Prefers sand	Littoral (<2m)	5 - 60	20 - 26	<20	1.0	Best at 236	1.7 - 2.0
Eelgrass (*Zostera marina*)	Usually sand	Littoral (0.25-1.5m)	5 - 35	8 - 35	<15	1.25	Best at 220	[ ]
Baltic clam (*Macoma balthica*)	All substrates; best in mud	Intertidal; Subtidal to 15m	2 - 19	[ ]	[ ]	[ ]	N.L.	N.L.
Brackish-water clam (*Rangia cuneata*)	Mud/sand mix	Intertidal; Subtidal to 5m	0 - 18	8 - 32	[ ]	[ ]	N.L.	N.L.
Crustaceans Insects Small fish								

(1) Stevenson (unpublished data)
(2) Orth and Moore (unpublished data)

(Cont'd)

Matrix of Habitat Requirements for
Canvasback (*Aythya valisneria*)
Critical life stage: wintering
Critical Life period: November - March

Target Species	DIN (1) (mg/l)	DIP (1) (mg/l)	Herbicides (ug/l)	Metals (mg/l)	Chlorophyll a (1,2) (ug/l)	DO (mg/l)	pH
Canvasback (*Aythya valisneria*)	N.L.	N.L.	N.L.	[ ]	N.L.	N.L.	N.L.
PREY SPECIES:							
Wild celery (*Vallisneria americana*)	<0.7-14	<0.01	Mortality at 12 atrazine	[ ]	<15	N.L.	6 - 9
Sago pondweed (*Potamogeton pectinatus*)	<0.14	<0.01	250 diquat or paraquat controls	[ ]	<15	N.L.	6 - 9
Redhead grass (*Potamogeton perfoliatus*)	<0.14	<0.01	Signficantly reduced photosynthesis at 50	[ ]	<15	N.L.	6 - 9
Widgeongrass (*Ruppia maritima*)	<0.14	<0.01	[ ]	[ ]	<15	N.L.	6 - 9
Eelgrass (*Zostera marina*)	[ ]	[ ]	Mortality at 100 - 1000 atrazine	[ ]	<10	N.L.	6 - 9
Baltic clam (*Macoma balthica*)	[ ]	[ ]	[ ]	Accumulates metals; toxicity not known	[ ]	[ ]	N.L.
Brackish-water clam (*Rangia cuneata*)	[ ]	[ ]	[ ]	[ ]	[ ]	Withstands anoxia for days. Intolerant of air exposure	[ ]
Crustaceans Insects Small Fish							

(1) Stevenson (unpublished data)
(2) Orth and Moore (unpublished data)

Matrix of Habitat Requirements for
Redhead Duck (*Aythya americana*)
Critical life stage: All life stages
Critical Life period: April - September

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Turbidity (mg/l)	Secchi Depth (m)	Light Intensity (u/E/m-2/S-1)	KD (m-1)	pH
Redhead duck (*Aythya americana*)	N.L.	N.L.	N.L.	N.L.	N.L.	2.0	N.L.	N.L.	N.L.
FOOD ITEMS:									
Wild celery (*Vallisneria americana*)	Silt-clay sand	Littoral (3m)	0-5	18-35	<20	1.0	Best at 100	[ ]	6-9
Sago pondweed (*Potamogeton pectinatus*)	Mud better than sand	Littoral (3m)	0-12	15-35	<20	1.0	Best at 350	1.7-2.0	6-9
Redhead grass (*Potamogeton perfoliatus*)	Mud, some organics	Littoral (3m)	2-19	15-35	<20	1.0	Best at 230	1.7-2.0	6-9
Widgeongrass (*Ruppia maritima*)	Prefers sand	(<2m)	5-60	20-26	<20	1.0	Best at 236	1.7-2.0	6-9
Eelgrass (*Zostera marina*)	Usually sand	0.25-1.5 m	5-35	8-35	<15	1.25	Best at 220	[ ]	6-9
Crustaceans Insects Small fish									

(1) Stevenson (unpublished data)
(2) Orth and Moore (unpublished data)

(cont'd)

Matrix of Habitat Requirements for

Redhead Duck (*Aythya americana*)

Critical life stage: All life stages

Critical Life period: April - September

Target Species	Chlor.	DIN	DIP	Herbicides	Metals
Redhead duck (*Aythya americana*)	N.L.	N.L.	N.L.	N.L.	N.L.
FOOD ITEMS:					
Wild celery (*Vallisneria americana*)	<15	<0.7-1.4	<0.01	Mortality at 12 atrazine	[ ]
Sago pondweed (*Potamogeton pectinatus*)	<15	<0.14	<0.01	250 diquat or paraquat controls	[ ]
Redhead grass (*Potamogeton perfoliatus*)	<15	<0.14	<0.01	Significantly reduced photo-synthesis at 50	[ ]
Widgeongrass (*Ruppia maritima*)	<15	<0.14	<0.01	[ ]	[ ]
Eelgrass (*Zostera marina*)	<10	[ ]	[ ]	Mortality at 100-1000 atrazine	[ ]
Crustaceans Insects Small fish					

(1) Stevenson (unpublished data)
(2) Orth and Moore (unpublished data)

of its wintering time in waters at or near ocean salinity. Entire winters may be spent on the water.

The food of the redhead consists largely of vegetation, more so than other diving ducks. Sago pondweed, wild celery, widgeongrass and other submerged aquatic plants are the favored items. A small percentage of insects, mollusks, other invertebrates, and small fish are also eaten.

TARGET SPECIES: Black Duck (*Anas rubripes*)
Critical Life Stage: nestling
Critical Life Period: April - July

BACKGROUND

The Chesapeake Bay's population of black ducks has dwindled in recent years, from an estimated 200,000 overwintering in 1955 to less than 50,000 in the mid-1980s. For this reason, more severe hunting restrictions have been placed upon the species.

Black ducks pair in the autumn. Typically in April, the female lays from 7 to 12 eggs in simple, hollowed-out, pine needle-lined nests. In the Chesapeake Bay area, isolated islands and marshes are the favored breeding places. Though wary of people and other intruders such as predators, which include raccoons, crows and gulls, almost half the nests are usually destroyed. A second clutch of eggs is then usually laid.

Black ducks feed on animal foods more than most other dabblers. Favored items are snails, mussels, clams, small crustaceans and immature insects. Pondweeds (*Potamogeton* spp.), widgeongrass, eelgrass, smooth cordgrass, wild rice and bulrushes are plant food items which, along with corn, are consumed when available.

TARGET SPECIES: Wood duck (*Aix sponsa*)
Critical Life Stage: nestling
Critical Life Period: April - July

BACKGROUND

Wood ducks are at the northern edge of their wintering range in the Chesapeake area, but can breed successfully, given proper habitat. Breeding habitat should include 10 acres of isolated wetlands with at least 50 percent cover, while wintering habitats may be less dependent on size given the adults' greater sociability and mobility. Typical habitat consists of secluded freshwater swamps and marshes providing plenty of downed or overhanging trees, shrubs, and flooded woody vegetation. Areas inhabited by beaver often provide good wood duck habitat. Cavity nesting sites are important for wood ducks, in order to provide safety from predators such as raccoons.

Adults are largely herbivorous, typically feeding on nuts and fruits from woody plants, aquatic plants and seeds. Their diet does include some insects

Matrix of Habitat Requirements for
Black Duck (*Anas rubripes*)
Critical life stage: nestling
Critical Life period: April - July

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Secchi Depth (m)	Cover	Light Intensity (uE/m-2/s-1)	Metals (mg/l)	Herbicides (ug/l)
Black duck (*Anas rubripes*)	[ ]	N.L.	N.L.	N.L.	1.0 - needs intertidal feeding areas	Marsh vegetation	N.L.	Lead shot ingested	[ ]
PREY SPECIES:									
Wild celery (*Vallisneria americana*)	Silt-clay-sand	Littoral (3m)	0-5	18-35	1.0	N.L.	Best at 100	[ ]	Mortality at 12 atrazine
Sago pondweed (*Potamogeton pectinatus*)	Mud better than sand	Littoral (3m)	0-12	15-35	1.0	N.L.	Best at 350	[ ]	250 diquat or paraquat controls
Redhead grass (*Potamogeton perfoliatus*)	Mud, some organics	Littoral (3m)	2-19	15-35	1.0	N.L.	Best at 230	[ ]	Significantly reduced photo-synthesis at >50
Widgeongrass (*Ruppia maritima*)	Prefers sand	Littoral (<2m)	5-60	20-26	1.0	N.L.	Best at 236	[ ]	[ ]
Smartweeds (*Polygonum* spp.)	[ ]	[ ]	[ ]	N.L.	N.L	N.L.	[ ]	[ ]	[ ]
Rice cutgrass (*Leevsia oryzoid*)	[ ]	[ ]	[ ]	N.L.	N.L	N.L.	[ ]	[ ]	[ ]
Cordgrass (*Spartina alterniflora*)	[ ]	[ ]	[ ]	N.L.	N.L.	N.L.	[ ]	[ ]	[ ]
Salt marsh snail (*Melampus bidentatus*)	[ ]	[ ]	[ ]	[ ]	N.L.	[ ]	[ ]	[ ]	[ ]

(1) Stevenson (Unpublished data)
(2) Orth and Moore (Unpublished data)

(cont'd)
Matrix of Habitat Requirements for
Black Duck (*Anas rubripes*)
Critical life stage: nestling
Critical Life period: April - July

Target Species	Turbidity (NTU)	KD (m-1)	Chlor. (ug/l)	DIN (1) (mg/l)	DIP (1) (mg/l)	pH
Black duck (*Anas rubripes*)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:						
Wild celery (*Vallisneria americana*)	<20	[ ]	<15 (1)	<0.7-1.4	<0.01	6-9
Sago pondweed (*Potamogeton pectinatus*)	<20	1.7-2.0	<15 (1)	<0.14	<0.01	6-9
Redhead grass (*P. perfoliatus*)	<20	1.7-2.0	<15 (1)	<0.14	<0.01	6-9
Widgeongrass (*Ruppia maritima*)	<20	1.7-2.0	<15 (1)	<0.14	<0.01	6-9
Smartweeds (*Polygonum* spp.)	N.L.	N.L	N.L.	N.L.	N.L.	N.L.
Rice cutgrass (*Leevsia oryzoides*)	N.L.	N.L	N.L.	N.L.	N.L.	N.L.
Cordgrass (*Spartina alterniflora*)	N.L.	N.L	N.L.	N.L.	N.L.	N.L.
Salt marsh snail (*Melampus bidentatus*)	N.L.	N.L	N.L.	N.L.	N.L.	N.L.

(1) Stevenson (Unpublished data)
(2) Orth and Moore (Unpublished data)

Matrix of Habitat Requirements for
Wood Duck (*Aix sponsa*)
Critical life stage: wintering
Critical Life period: November to March

Target Species	Cover	Salinity (ppt)
Wood Duck (*Aix sponsa*)	Needed for young	N.L.
PREY SPECIES:		
Arrow-arum (*Peltandra virginica*)	N.L.	0
Giant burreed (*Sparganium eurycarpum*)	N.L.	0
Tearthumb (*Polygonum* spp.)	N.L.	0
Oaks (*Quercus* spp.)		0
Potamogeton spp.	N.L.	0-12
Nuts		
Aquatic invertebrates		
Fruits		
Insects		

(1) U.S. Fish and Wildlife Service (unpublished data)

and aquatic invertebrates. During the egg laying period, adult wood duck hens have high protein and calcium requirements, satisfied mainly through an invertebrate diet. Young ducklings up to 6 weeks of age also ingest a high percentage of invertebrates, chiefly insects.

TARGET SPECIES: Great blue heron (*Ardea herodeas*)
Critical Life Stage: nestling
Critical Life Period: May-July

BACKGROUND

Habitat for the great blue heron includes wooded areas suitable for colonial nesting and wetlands within a specified distance (e.g. 1 kilometer) of a heronry where foraging can occur. The heronry area itself can be an acre or two in size, but is preferably isolated. Most great blue heron colonies in the Bay area are located in riparian swamps with trees tall enough for nest placement at 5 to 15 m above ground. Other wading bird species may coexist in a great blue heronry. Four eggs are typically laid by the adult female, with an incubation period of four weeks.

Great blue herons feed alone or occasionally in flocks. Feeding usually occurs during the day, but occasionally takes place at night. Both still-hunting and stalking techniques are used to hunt for fish which is their main prey. Herons also eat frogs, lizards, snakes, small birds, mammals, and insects. Usually, feeding is limited to clear waters less than 0.5 m in depth, with firm substrate. Contaminants in the food chain have been documented as a problem, especially dieldrin and DDE and possibly other organochlorines, which cause eggshell thinning.

TARGET SPECIES: Great (American) egret (*Casmerodius albus*)
Critical Life Stage: nestling
Critical Life Period: June - August

BACKGROUND

Habitat needs of the great heron are similar to those of the great blue heron; a heronry area preferably isolated, with good roosting trees and a foraging area close by. Fresh, brackish and salt water marshes are all used for foraging.

Three or four eggs, incubating in about 24 days, are typically produced. The large nests can be from 6 to greater than 15 meters high, located in large trees near the water. Crows and vultures may prey on the eggs when left unattended. The young of the year sometimes wander northward before migrating southward for the winter.

The food of the great egret consists of small fish from the shallow waters, as well as frogs, lizards, small snakes, crustaceans, mollusks and insects. The depth of water in which foraging takes place is usually less than 25 cm.

Matrix of Habitat Requirements for
Great blue heron (*Ardea herodeas*)
Critical life stage: nestling
Critical Life period: May to July

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (mg/l)
Great blue heron (*Ardea herodeas*)	Firm better	Intertidal, shallow	N.L.	N.L.	Estuarine	N.L.	0.5	[ ]	[ ]
PREY SPECIES: (1)									
Atlantic silversides (*Menidia menidia*)	Prefer hard, vegetated- Needed for eggs, young	Intertidal	Tolerate 1-34 Prefer 3-14	Juveniles: Tolerate 3-31 Prefer 18-25	[ ]	>5.0	[ ]	[ ]	Endrin <0.05
Mummichog (*Fundulus heteroclitus*)	Prefer mud	Intertidal	0-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <10 (2)
Striped killfish (*Fundulus majalis*)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mammals Amphibians									

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants

Matrix of Habitat Requirements for
Great egret (*Casmerodius albus*)
Critical life stage: nestling
Critical Life period: June to August

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (ug/l)
Great Egret (*Casmerodius albus*)	Firm better	Intertidal	N.L.	N.L.	Estuarine	N.L.	0.25	[ ]	[ ]
PREY SPECIES: (1)									
Atlantic silversides (*Menidia menidia*)	Prefer hard, vegetated- Needed for eggs,young.	Intertidal	Tolerate 1-34, Prefer 3-14	Juveniles: Tolerate 3-31, Prefer 18-25	[ ]	>5.0	[ ]	[ ]	Endrin <0.05
Mummichog (*Fundulus heteroclitus*)	Prefer mud	Intertidal	0-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <1.0 (2)
Striped killfish (*Fundulus majalis*)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mammals Amphibians									

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants

TARGET SPECIES: Little blue heron (*Florida caerulea*)
Critical Life Stage: nestling
Critical Life Period: June - August

BACKGROUND

The little blue heron breeds in the Chesapeake Bay area, but winters to the south. This heron's habitat includes fresh and salt water marshes where it seeks to avoid human activity. The heronry is typically situated in dense vegetation on or near a secluded small water body, often far inland from the larger marsh.

Food for little blue herons consists of minnows, crustaceans, insects such as grasshoppers, small frogs, lizards and worms. The little blue heron is an active feeder. Organochlorine residues have probably found their way into tissues and eggshells, but resulting physiological problems have not been noted.

TARGET SPECIES: Green heron (*Butorides striatus*)
Critical Life Stage: nestling
Critical Life Period: June - August

BACKGROUND

The green heron breeds in the Chesapeake Bay area and winters further to the south. Habitat for the green heron consists of either fresh or saltwater marsh. This heron appears to be more tolerant of human activity than some other heron species. The green heron nests singly or in small colonies, unlike the large heronries of other species. Their nests are not necessarily located near the water. Four to five eggs are usually laid, with incubation taking 17 days.

Food of the green heron includes minnows, tadpoles, water insects and their larvae, and crustaceans. They occasionally feed in the uplands where prey includes worms, insects such as crickets and grasshoppers, snakes and small mammals.

TARGET SPECIES: Snowy egret (*Egretta thula*)
Critical Life Stage: nestling
Critical Life Period: June - August

BACKGROUND

The snowy egret breeds in the Chesapeake Bay area and winters to the south. Both fresh and saltwater marshes are typical habitats for the snowy egret. Large rookeries, preferably in isolated sections of a marsh, are favored. Nests usually range in height from 3 to 6 meters in small trees.

Matrix of Habitat Requirements for
Little blue heron (*Florida caerulea*)
Critical life stage: nestling
Critical Life period: June-August

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (ug/l)
Little blue heron (*Florida caerulea*)	Firm better	Intertidal	N.L.	N.L.	Estuarine	N.L.	0.25	[ ]	[ ]
PREY SPECIES: (1)									
Atlantic silversides (*Menidia menidia*)	Prefer hard, vegetated- Needed for eggs, young.	Intertidal	Tolerate 1-34. Prefer 3-14	Juveniles tolerate 3-31, Prefer 18-25	[ ]	>5.0	[ ]	[ ]	Endrin <0.05
Mummichog (*Fundulus heteroclitus*)	Prefer mud	Intertidal	0-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <1.0 (2)
Striped killfish (*Fundulus majalis*)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mammals Amphibians									

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants.

Matrix of Habitat Requirements for
Green Heron (*Butorides striatus*)
Critical life stage: nestling
Critical Life period: June-August

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (ug/l)
Green heron (*Butorides striatus*)	Firm better	Intertidal	N.L.	N.L.	Tidal, nontidal wetlands	N.L.	0.25	[ ]	[ ]
PREY SPECIES: (1)									
Atlantic silversides (*Menidia menidia*)	Prefer hard, vegetated- Needed for eggs, young.	Intertidal	Tolerate 1-34, Prefer 3-14	Juveniles: Tolerate 3-31, Prefer 18-25	[ ]	>5.0	[	[ ]	Endrin <0.05
Mummichog (*Fundulus heteroclitus*)	Prefer mud	Intertidal	0-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <10 (2)
Striped killfish (*Fundulus majalis*)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mammals Amphibians									

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants

Matrix of Habitat Requirements for
Snowy Egret (*Egretta thula*)
Critical life stage: nestling
Critical Life period: June to August

Target Species	Substrate	Zone	Salinity (ppt)	Temp. (C)	Flow (cm/s)	DO (mg/l)	Secchi Depth (m)	Metals (mg/l)	Chlorinated Hydrocarbons (ug/l)
Snowy egret (*Egretta thula*)	Firm better	Intertidal	N.L.	N.L.	Tidal, nontidal	N.L.	0.25	[ ]	[ ]
PREY SPECIES: (1)									
Atlantic silversides (*Menidia menidia*)	Prefer hard, vegetated- Needed for eggs, young.	Intertidal	Tolerate 1-34 Prefer 3-14T	Juveniles: Tolerate 3-31, Prefer 18-25	[ ]	>5.0	[ ]	[ ]	Endrin <0.05
Mummichog (*Fundulus heteroclitus*)	Prefer mud	Intertidal	0-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <1.0 (2)
Striped killfish (*Fundulus majalis*)	Prefer sand	Intertidal	1-30	[ ]	[ ]	>5.0	[ ]	(2)	Endrin <0.3 (2)
Reptiles Insects Crustaceans Small mammals Amphibians									

(1) U.S. Fish and Wildlife Service (unpublished data)
(2) Eisler (1986) lists toxicity information on 118 toxicants

The snowy egret usually produces 4-5 eggs which incubate in about 18 days. Both parents share in nesting chores. Food consists of small fish, insects, crayfish, small snakes, frogs and lizards.

TARGET SPECIES: Bald eagle (*Haleaeetus leucocephalus*)
Critical Life Stage: nestling
Critical Life Period: late-January to mid-June

BACKGROUND

The southern bald eagle is still endangered but has been making a come-back in the Chesapeake Bay area -- it was estimated that 136 pairs occupied nests in 1986. The bald eagle breeds in the Bay area and a select number migrate south in autumn. Others remain in congregations in areas such as Caledon State Park, VA, on the Potomac River.

Habitat for the bald eagle is typically close to the water, where tall trees provide good perching places for the bird to observe prey. The bald eagle avoids human activities and it will usually not vigorously defend a nest.

Two to three eggs are produced, laid in a large nest up to 7 feet high by 7 feet across. The nest may be 60 feet or more above ground placed in large trees. About 35 days are required for incubation of eggs.

Food of bald eagles consists primarily of fish, which is often found dead by the birds. Other dead animals may also be taken. The bald eagle will also take other prey alive such as ducks, and small to medium mammals. The problem of organochlorine pesticide residues which caused eggshells to thin and hatch success to be reduced has been minimized.

TARGET SPECIES: Osprey (*Pandion halaetus*)
Critical Life Stage: nestling
Critical Life Period: April to mid-July

BACKGROUND

The Chesapeake Bay region supports over 1,500 nesting pairs of ospreys. Ospreys always live near the water, roosting in large trees and building large, bulky, stick-nests in trees or on poles or platforms. The osprey can learn to tolerate human disturbance near its nest. After the breeding and rearing season is complete, the birds migrate to tropical wintering grounds.

Ospreys feed almost exclusively on live fish taken from near-surface waters. Nearly every common Chesapeake Bay species of fish has been recorded in the osprey's diet. Situated at the top of the food chain, ospreys experienced trouble with accumulated organochlorine pesticide residues of DDT and dieldrin some years ago. The problems of thinned eggshells and poor hatch rates experienced at the time, have apparently been rectified, and the birds are doing well in the Bay.

Matrix Habitat Requirements for
Bald Eagle (*Haliaeetus leucocephalus*)
Critical life stage: nestling
Critical life period: late January to mid-June

Target Species	Cover	Salinity (ppt)	Temp. (C)	Metals	DO (mg/l)	pH	Turbidity (NTU)	Suspended solids (mg/l)
Bald Eagle (*Haliaeetus leucocephalus*)	Quiet area near water, with tall trees	N.L.	N.L.	lead shot ingested: 11.3 ppm in kidney is fatal.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:								
Striped bass (*Morone saxatilis*)	[ ]	0-5 (1)	16-19	*	6-12	7-8*	[ ]	[ ]
American shad (*Alosa sapidissima*)	[ ]	0-15 (2,3)	15.5-26	[ ]	>5 (4)	6.5-8.5 (4,5)	<50 (4)	<50 (5)
Menhaden (*Brevoortia tyrannus*)	[ ]	0-15 (2)	10-30	[ ]	>5 (4,6)	6.5-8.5 (4,6)	[ ]	[ ]
Alewife (*Alosa pseudoharengus*)	[ ]	0-5*	16-25	[ ]	>5	6.5-8.5 (4)	[ ]	<50
White Perch (*Morone americana*)	[ ]	0-8*	12-20*	[ ]	>5 (4)	6.5-8.5 (4)	<50 (4)	<70 (4)
Yellow Perch (*Perca flavescens*)	SAV, Submerged trees	0-0.5	10-19	[ ]	>5 (4)	6.5-8.5	<50 (4)*	<500 (1)*
Carrion Small mammals Turtles Birds								

* See target species habitat requirement matrices for more detailed information.
(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986
(4) Klein and O'Dell (1987)
(5) Connery (1987)
(6) U.S. Corps of Engineers (1984)
(7) Wang and Kernehan (1979)

(Cont'd)
Matrix of Habitat Requirements for
Bald Eagle (*Haliaeetus leucocephalus*)
Critical life stage: nestling
Critical Life period: April to mid-July

Target Species	Substrate	Zone	Flow (m/s)	Alkalinity (mg/l)	Pathogen	Metals (mg/l)	Insecticides (mg/l)
Bald Eagle (*Haliaeetus leucocephalus*)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:							
Striped bass (*Morone saxatilis*)	[ ]	Water column demersal	0.3-5.0 (1)	>20	[ ]	*	*
American shad (*Alosa sapidissima*)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Menhaden (*Brevoortia tyrannus*)	[ ]	Pelagic or open waters	[ ]	[ ]	Fungal parasites	[ ]	[ ]
Alewife (*Alosa pseudoharengus*)	Sand, gravel w/75% silt	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
White Perch (*Morone americana*)	Compact silt, sand, mud clay	Subsurface waters (7)	[ ]	[ ]	[ ]	*	DDT LC50 - 8.0 Dieldrin LC50 - 10.0
Yellow Perch (*Perca flavescens*)	*	Demersal*	[ ]	[ ]	[ ]	[ ]	[ ]

* See target species habitat requirement matrices for more detailed information.
(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986
(4) Klein and O'Dell (1987)
(5) Connery (1987)
(6) U.S. Corps of Engineers (1984)
(7) Wang and Kerneham (1979)

Matrix of Habitat Requirements for
Osprey (*Pandion haliaetus*)
Critical life stage: nestling
Critical Life period: April to mid-July

Target Species	Cover	Salinity (ppt)	Temp. (C)	TRC (mg/l)	DO (mg/l)	pH	Turbidity (NTU)	Suspended Solids (mg/l)
Osprey (*Pandion haliaetus*)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:								
Striped bass (*Morone saxatilis*)	[ ]	0-5 (1)	16-19	*	7-8*	[ ]	[ ]	[ ]
American shad (*Alosa sapidissima*)	[ ]	0-15 (2,3)	15.5-26	[ ]	>5 (4)	6.5-8.5 (4,5)	<50 (4)	<50 (5)
Menhaden (*Brevoortia tyrannus*)	[ ]	0-15 (2)	10-30	[ ]	>5 (4,6)	6.5-8.5 (4,6)	[ ]	[ ]
Alewife (*Alosa pseudoharengus*)	[ ]	0-5*	16-25	[ ]	>5	6.5-8.5 (4)	[ ]	<50
White Perch (*Morone americana*)	[ ]	0-8*	12-20*	0.15	>5 (4)	6.5-8.5 (4)	<50 (4)	<70 (4)
Yellow Perch (*Perca flavescens*)	SAV, Submerged trees	0-0.5	10-19	[ ]	>5 (4)	6.5-8.5	<50 (4)	<500 (1)

* See target species habitat requirement matrices for more detailed information.
(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986
(4) Klein and O'Dell (1987)
(5) Connery (1987)
(6) U.S. Corps of Engineers (1984)
(7) Wang and Kernehan (1979)

(Cont'd)

Matrix of Habitat Requirements for

Osprey (*Pandion haliaetus*)

Critical life stage: nestling

Critical Life period: April to mid-July

Target Species	Substrate	Zone	Flow (m/s)	Alkalinity (mg/l)	Pathogen	Metals (mg/l)	Insecticides (mg/l)
Osprey (*Pandion haliaetus*)	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
PREY SPECIES:							
Striped bass (*Morone saxatilis*)	[ ]	Water column demersal	0.3-5.0 (1)	>20	[ ]	*	*
American shad (*Alosa sapidissima*)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Menhaden (*Brevoortia tyrannus*)	[ ]	Pelagic or open waters	[ ]	[ ]	Fungal parasites	[ ]	[ ]
Alewife (*Alosa pseudoharengus*)	Sand, gravel w/75% silt	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
White Perch (*Morone americana*)	Compact silt, sand, mud clay	Subsurface waters (7)	[ ]	[ ]	[ ]	*	DDT LC50 - 8.0 Dieldrin LC50 - 10.0
Yellow Perch (*Perca flavescens*)	*	Demersal*	[ ]	[ ]	[ ]	[ ]	[ ]

*See target species habitat requirement matrices for more detailed information.

(1) Westin and Rogers (1978)
(2) Kaumeyer and Setzler-Hamilton (1982)
(3) FWS Habitat suitability index publications Biological Report 82(11.45) 1986
(4) Klein and O'Dell (1987)
(5) Connery (1987)
(6) U.S. Corps of Engineers (1984)
(7) Wang and Kerneham (1979)

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(3) American shad	Biological Report 82(10.88) 1985 27 pp.
Hickory shad	Biological Report 82(11.45) 1986 15 pp.
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(4) Yellow perch	FWS/OBS 82/10.55 1983 32 pp
(5) White perch	FWS/OBS 82/.11.7 1983 10 pp.
(6) Menhaden	FWS/OBS 82/11.11 1983. 15 pp.
(7) Spot	FWS/OBS 82/10.20 1982 10 pp.

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APPENDIX A:

TOXICITY OF SUBSTANCES TO STRIPED BASS LARVAE AND JUVENILES

Adapted from Westin and Rogers. 1978.

Synopsis of Biological Data on the Striped Bass, _Morone saxatilis_ (Walbaum) 1972. University of Rhode Island, Marine Technical Report 67, Kingston, RI

-TABLE 1-

TOXICITY OF SUBSTANCES TO STRIPED BASS LARVA

SUBSTANCE	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
Acriflavine	5.0 (NA)	Hughes (1973)
Aldrin	0.01 (NA)	Hughes (1973)
Amifur	10.0 (NA)	Hughes (1973)
Butyl ester of 2,4-D	0.15 (NA)	Hughes (1971)
Cadmium	0.001 (NA)	Hughes (1973)
Chloride	1000 (NA)	Hughes (1973)
Chlorine	0.20 (NA)	Morgan & Prince (1977)
	0.40-0.07 incipient	Middaugh et al. (1977)
Copper	0.05 (NA)	Hughes (1973)
Copper	0.31 (0.12-3.08)	O'Rear (1971)
Copper sulfate	0.1 (NA)	Hughes (1971)
Dieldrin	0.001 (NA)	Hughes (1973)
Diquat	1.0 (NA)	Hughes (1973)
Diuron	0.5(NA)	Hughes (1973)
Dylox	5.0 (NA)	Hughes (1971)
Ethyl parathion	2.0 (NA)	Hughes (1971)
Formaldehyde	10.0 (NA)	Hughes (1973)
HTH	0.5 (NA)	Hughes (1971)
Iron	4.0 (NA)	Hughes (1973)
Karmex	0.5 (NA)	Hughes (1971)
Malachita green	0.05 (NA)	Hughes (1973)
Methylene blue	1.0 (NA)	Hughes (1973)
Methyl parathion	5.0 (NA)	Hughes (1971)
Potassium dichromate	100 (NA)	Hughes (1971)
Potassium permanganate	1.0 (NA)	Hughes (1971)
Roccal	0.5 (NA)	Hughes (1973)
Rotenone	0.001 (NA)	Hughes (1973)
Sulfate	250 (NA)	Hughes (1973)
Tad-Tox	5.0 (NA)	Hughes (1973)
Terramycin	50.0 (NA)	Hughes (1973)
Zinc	0.1 (NA)	Hughes (1973)
Zinc	1.18 (0.25-2.46)	O'Rear (1971)

a All 4-7 day-old larvae from Moncks Corner, South Carolina, tested at 21 C, except O'Rear (1971) which were tested in 14-19 C range, Morgan & Prince (1977) not specified, and Middaugh et al. (1977) at 18 C.

b NA = not available (i.e., neither given nor calculatable).

c 48-hour TLm

d 96-hour LCo

e 24-hour TLm

-TABLE 2-

TOXICITY OF SUBSTANCES TO JUVENILE STRIPED BASS

SUBSTANCE	TEST TEMP C	96-HOUR TLm (95% C.I.) (mg/1)	AUTHOR
Abate	13	1.0 (NA)	Korn & Earnest (1974)
Achromycin	21-22	190 (153.2-235.6)	Kelley (1969)
Acriflavine	21	27.5 (NA)	Hughes (1973)
		16.0 (14.7-17.4)	Wellborn (1971)
Aldrin	13	0.0072 (0.0034-0.0152	Korn & Earnest (1974)
	21	LCo 0.075 (NA)	Hughes (1973)
	20	0.010 (NA)	Rehwoldt et al. (1977)
Amifur	21	LCo 30.0 (NA)	Hughes (1973)
Ammonium hydroxide	15	1.9-2.85	Hazel et al. (1971)
	23	1.4-2.8	" " " "
Aquathol	21	610 (634-795)	Wellborn (1971)
Bayluscide	21	72 hr. 1.05 (0.94-1.18)	Wellborn (1971)
Benzene	17.4	10.9 ul/1 (+0.02)	Meyerhoff (1975)
	16	5.8 ul/1	Benville and Korn (1977)
Butyl ester of	21	3.0 (NA)	Hughes (1971)
2,4-D	20	70.0 (NA)	Rehwoldt et al. (1977)
Cadmium	21	0.002 (NA)	Hughes (1973)
Carbaryl	17	1.0 (NA)	Korn & Earnest (1974)
Casoron	21	6,2000 (5,210-7,378)	Wellborn (1971)
Chlordane	15	0.0118 (0.0057-0.024)	Korn & Earnest (1974)
Chloride	21	5000 (NA)	Hughes (1973)
Chlorine	18	0.04 incipient	Middaugh et al. (1977)
Cooling Tower	4.5-6.0	>4.0X	Texas Instruments (1974)
Blowdown and	18.5-26.0	>4.0X [incipient LC50	
Power Plant		w/o CL2, 3.6X	
Chemical Discharge		(3.81X -3.4X)]	
Co-Ral	21	62 (53-73)	Wellborn (1971)
Copper	21	0.05 (NA)	Hughes (1973)
	17	4.3 (NA)	Rehwoldt et al. (1971)
Copper sulfate	21	0.15 (NA)	Hughes (1971)
	21-22	0.6 (0.51-0.83)	Kelley (1969)
	21	0.62 (0.54-0.71)	Wellborn (1969)
Cutrine	21	0.1 (NA)	Hughes (1973)
DDD	17	0.0025 (0.0016-0.004)	Korn & Earnest (1974)
DDT	17	0.00053 (0.00038-0.00084)	Korn & Earnest (1974)
Dibrom	13	0.5 (0.1-2.4)	Korn & Earnest (1974)
Dieldrin	14	0.0197 (0.0098-0.00334)	Korn & Earnest (1974)
	21	0.25 (NA)	Hughes (1973)
Diquat	21	10.0 (NA)	Hughes (1973)
	21	80 (74-86)	Wellborn (1969)
Diuron (Karmex)	21	6.0 (NA)	Hughes (1973)

-TABLE 2 (cont.)-

SUBSTANCE	TEST TEMP C	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
Dursban	13	0.00058 (0.00035-0.00097)	Korn & Earnest (1974)
Dylox	21	2.0 (NA)	Hughes (1971)
		5.2 (4.2-8.0)	Wellborn (1969)
Endosulfan	16	0.0001 (0.000048-0.00021)	Korn & Earnest (1974)
Endrin	17	0.000094 (0.000045-0.00019)	Korn & Earnest (1974)
E.P.N.	18	0.60 (0.025-0.150)	Korn & Earnest (1974)
Ethyl parathion	21	1.0 (NA)	Hughes (1971)
	15	0.0178 (0.0048-0.0657)	Korn & Earnest (1974)
Fenthion	13	0.453 (0.216-0.955)	Korn & Earnest (1974)
Formaldehyde	21	15 (NA)	Hughes (1973)
	21-22	20 (15.4-26)	Kelley (1969)
	21	18 (10-32)	Wellborn (1969)
Heptachlor	13	0.003 (0.001-0.006)	Korn & Earnest (1974)
HTH	21	0.25 (NA)	Hughes (1971)
Instant Sea as (Cl)	21	LCo 17000 (NA)	Hughes (1973)
Iron	21	6.0 (NA)	Hughes (1973)
Karmex (Diuron)	21	6.0 (NA)	Hughes (1971)
		3.1 (2.5-3.9)	Wellborn (1969)
Lindane	21	0.40 (0.35-0.46)	Wellborn (1971)
	13	0.0073 (0.0045-0.0119)	Korn & Earnest (1974)
Malachite green	21	0.2 (NA)	Hughes (1973)
		24 hr. 0.30 (0.27-0.33)	Wellborn (1971)
Malathion	21	0.24 (0.20-0.29)	Wellborn (1971)
	13	0.014 (0.013-0.015)	Korn & Earnest (1974)
	20	0.039 (NA)	Rehwoldt et al. (1977)
Methoxychlor	15	0.0033 (0.0021-0.0051)	Korn & Earnest (1974)
Methylene blue	21	12.0 (NA)	Hughes (1973)
Methyl parathion	21	4.5 (NA)	Hughes (1971)
	13	0.79 (0.17-1.40)	Korn & Earnest (1974)
	20	14.0 (NA)	Rehwoldt et al. (1977)
MS-222	21-22	31.5 (25.6-37.5)	Kelley (1969)
	22-28	24 hr. 50.0 (NA)	Tatum et al. (1965)
MS-222 with 20 o/oo	21-22	31.5 (26.6-37.5)	Kelley (1969)
Nickel	17	6.2 (NA)	Rehwoldt et al. (1971)
Oil field brine (as Cl)	21	LCo 16600 (NA)	Hughes (1968)
Potassium dichromate	21	75 (NA)	Hughes (1971)
Potassium permanganate	21	4.0 (NA)	Hughes (1971)
	21-22	2.6 (2.17-3.12)	Kelley (1969)

-TABLE 2 (cont.)-

SUBSTANCE	TEST TEMP C	96-HOUR TLm (95% C.I.) (mg/l)	AUTHOR
	21	2.5 (2.1-2.9)	Wellborn (1969)
Polyotic	21	>1818 (NA)	Wellborn (1969)
PMA	21-22	1.1 (0.84-1.44)	Kelley (1969)
Quinaldine	21-22	4.5 (3.82-5.45)	Kelley (1969)
	22-28	24 hr. 22.0 (NA)	Tatum et al. (1965)
Quinaldine with 20 o/oo	21-22	5.0 (3.86-6.65)	Kelley (1969)
Reconstituted sea water	21-22	35 o/oo (NA)	Kelley (1969)
Roccal	21	1.5 (NA)	Hughes (1973)
Rotenone	21	LCo 0.001 (NA)	Hughes (1973)
Simazine	21	0.25 (0.17-0.36)	Wellborn (1969)
Sodium nitrilo-triacetic acid	20	5500 (NA)	Eisler et al. (1972)
Sulfate	21	3500 (NA)	Hughes (1973)
Syndet Ch	20	4.6 (NA)	Eisler et al. (1972)
Syndet Ga		8.7 (NA)	Eisler et al. (1972)
Tad-Tox	21	10.0 (NA)	Hughes (1973)
Terramycin	21	75.0 (NA)	Hughes (1973)
	21-22	170 (140.5-205.7)	Kelley (1969)
	21	178 (144-221)	Wellborn (1969)
		165 (147-185)	Wellborn (1971)
Toluene	16	7.3 ul/1	Benville & Korn (1977)
Toxaphene	17	0.0044 (0.002-0.009)	Korn & Earnest (1974)
m-xylene	16	9.2 (8.3-10) ul/1	Benville & Korn (1977)
Zinc	21	0.1 (NA)	Hughes (1973)
	17	6.7 (NA)	Rehwoldt et al. (1971)
2, 4, 5, T	20	14.6 (NA)	Rehwoldt et al. (1977)

a Unless specified otherwise

b NA = not available (i.e., neither given nor calculatable)

c Range of 96-hour TLm in freshwater, 33% sea water, and sea water (95% C.I. given for percent mortality at 0, 40, 60, 80, and 100%).

APPENDIX B:

HABITAT DISTRIBUTION MAPS OF CRITICAL LIFE STAGES OF THE TARGET CHESAPEAKE BAY LIVING RESOURCE SPECIES

List of Habitat Distribution Maps for the Critical Life Stages of the Target Chesapeake Bay Living Resource Species

1. 1986 Distribution of Submerged Aquatic Vegetation in Chesapeake Bay
2. Striped Bass (Morone saxatilis): Habitat Distribution of Legislatively Defined Spawning Reaches and Rivers in Chesapeake Bay
3. Blueback Herring (Alosa aestivalis): Habitat Distribution of Nursery Areas in Chesapeake Bay
4. Alewife (Alosa pseudoharengus): Habitat Distribution of Nursery Areas in Chesapeake Bay
5. American Shad (Alosa sapidissima): Habitat Distribution of Nursery Areas in Chesapeake Bay
6. Hickory Shad (Alosa mediocris): Habitat Distribution of Nursery Areas in Chesapeake Bay
7. Yellow Perch (Perca flavescens): Habitat Distribution of Spawning Areas in Chesapeake Bay
8. White Perch (Morone americana): Habitat Distribution of Spawning and Nursery Areas in Chesapeake Bay
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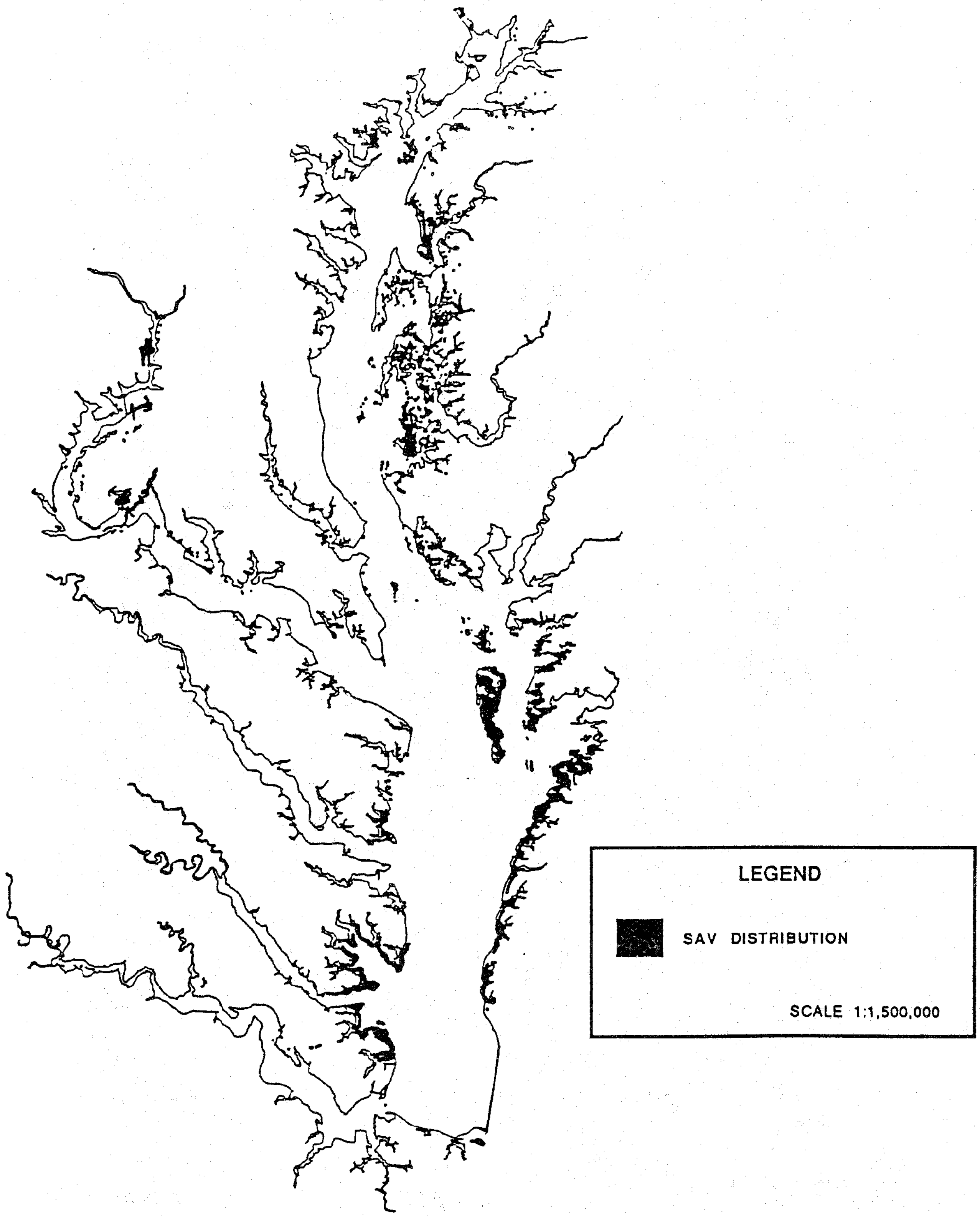
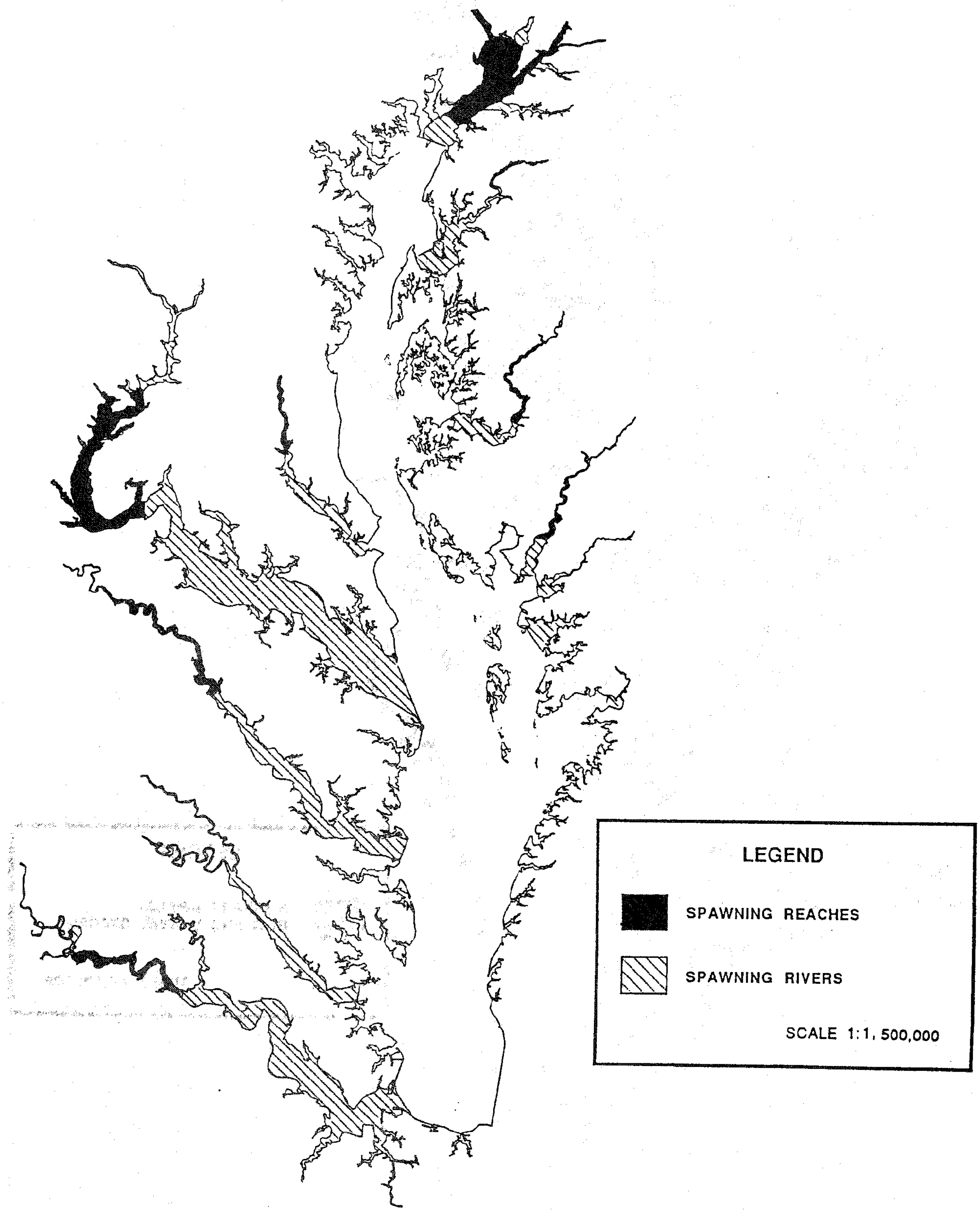
1986 DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN CHESAPEAKE BAY



SOURCE: Orth et al., 1987

FIGURE 1

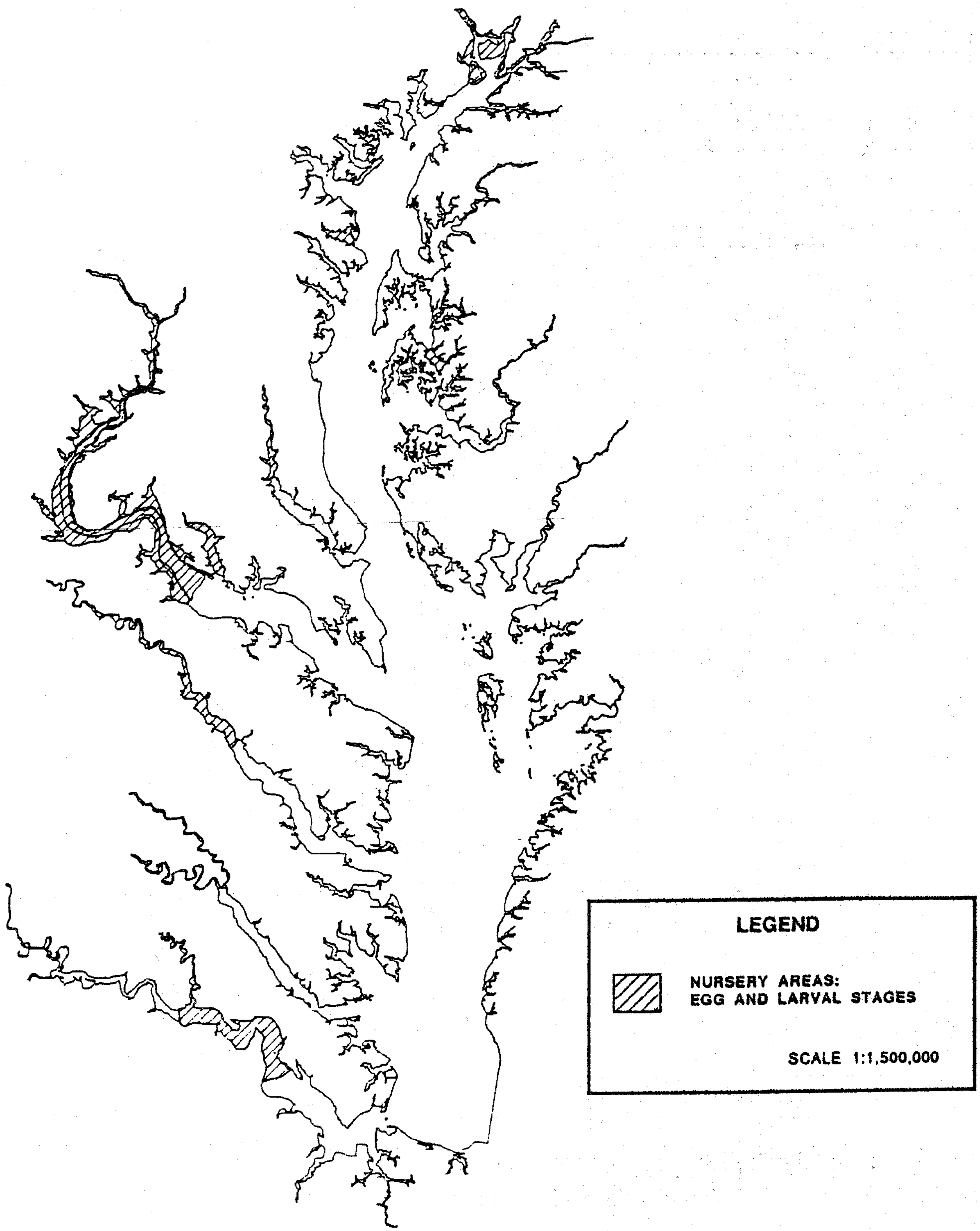
STRIPED BASS (*Morone saxatilis*): HABITAT DISTRIBUTION OF LEGISLATIVELY DEFINED SPAWNING REACHES AND RIVERS



SOURCES: Code of Maryland Regulations 08.02.05.02
Virginia Marine Resources Commission Regulation 450-01-0034

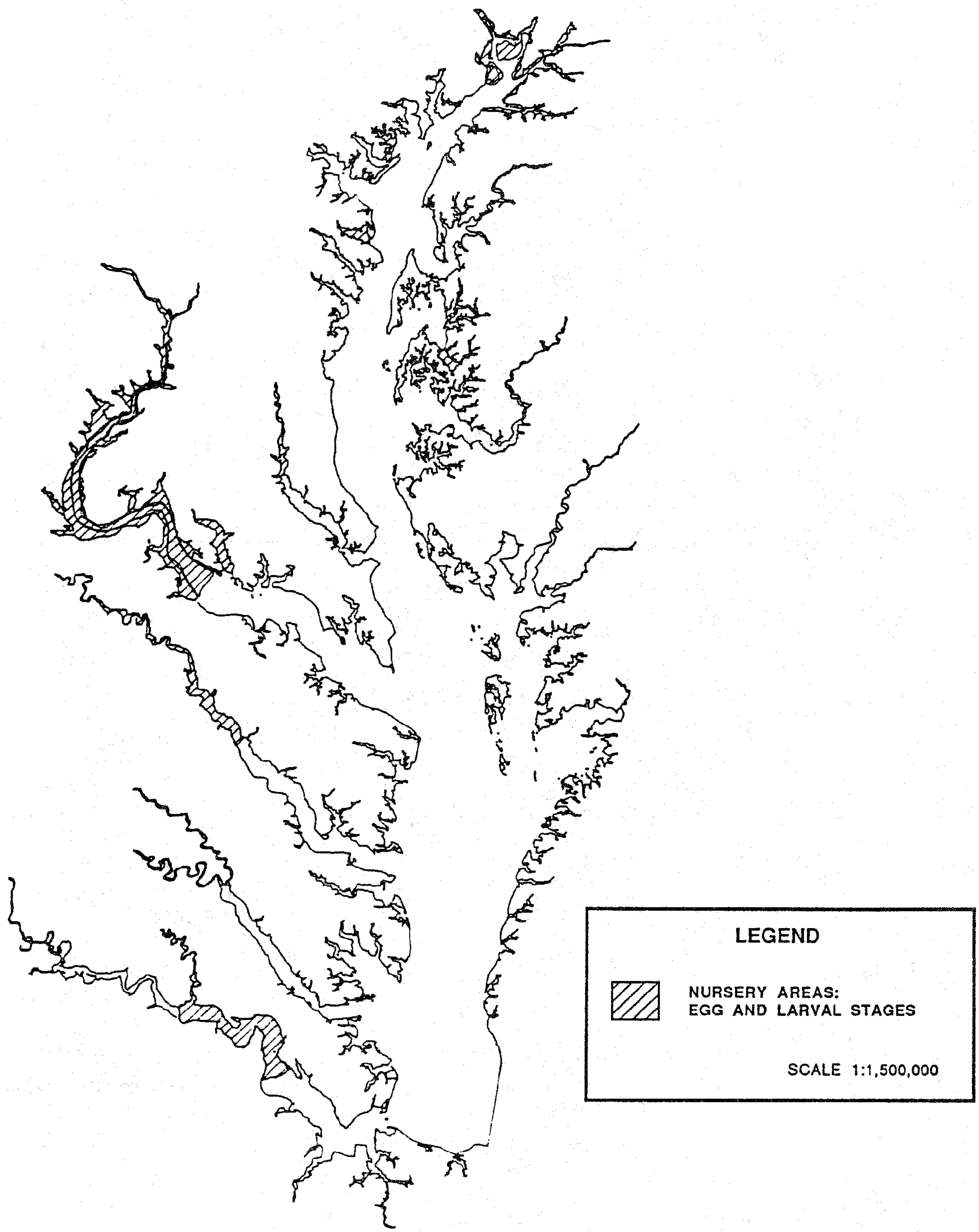
FIGURE 2

BLUEBACK HERRING (*Alosa aestivalis*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980 FIGURE 3

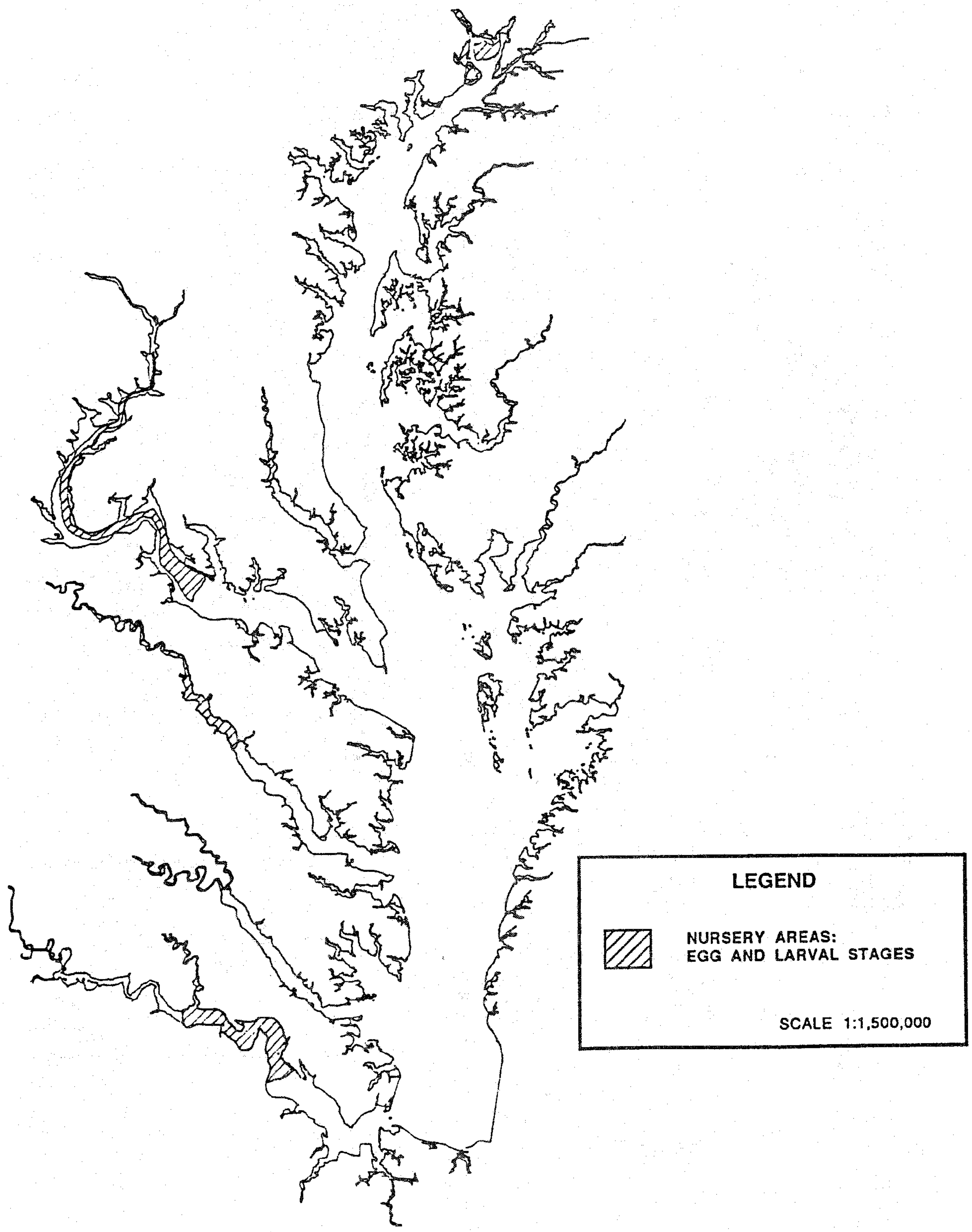
ALEWIFE (*Alosa pseudoharengus*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 4

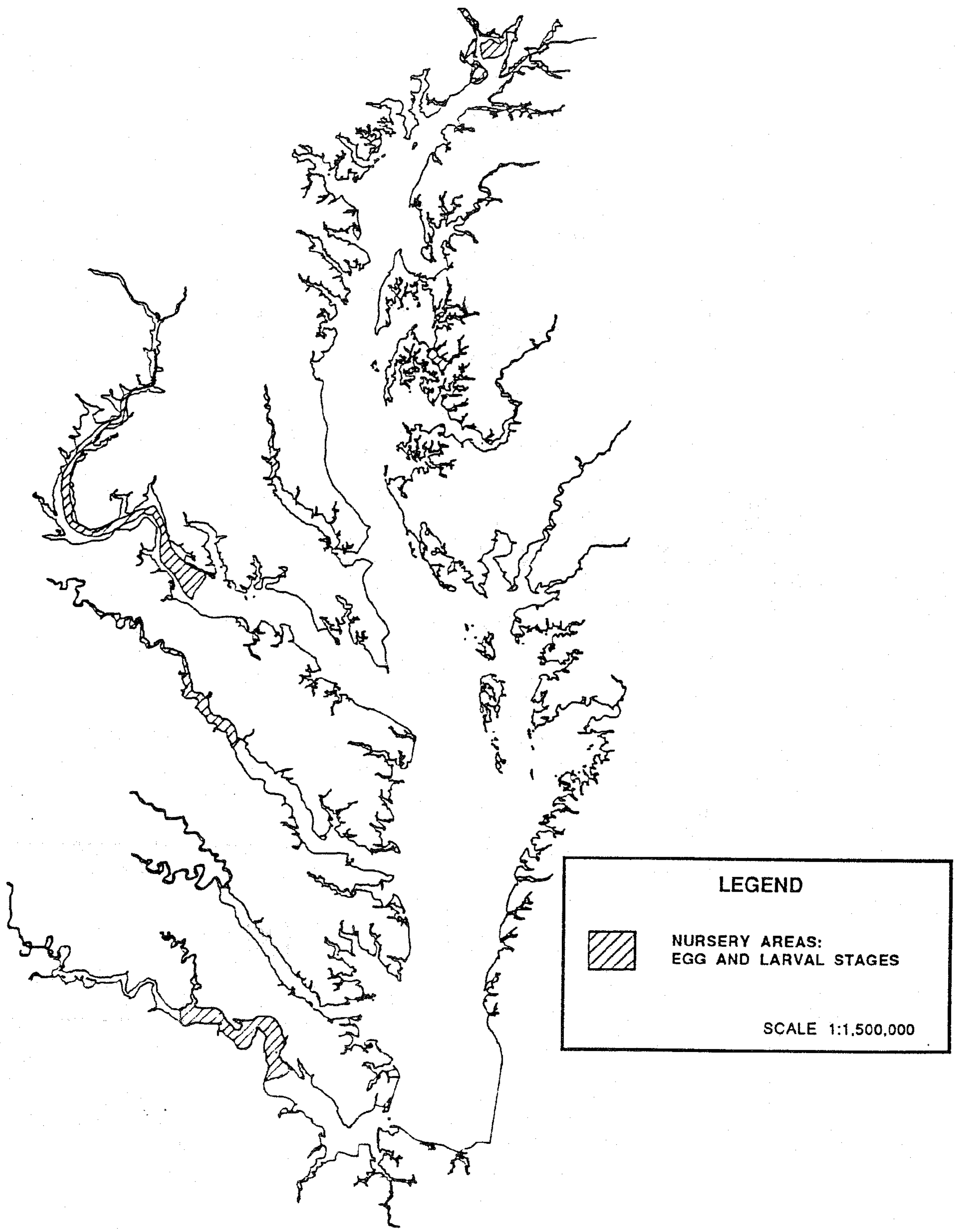
AMERICAN SHAD (*Alosa sapidissima*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 5

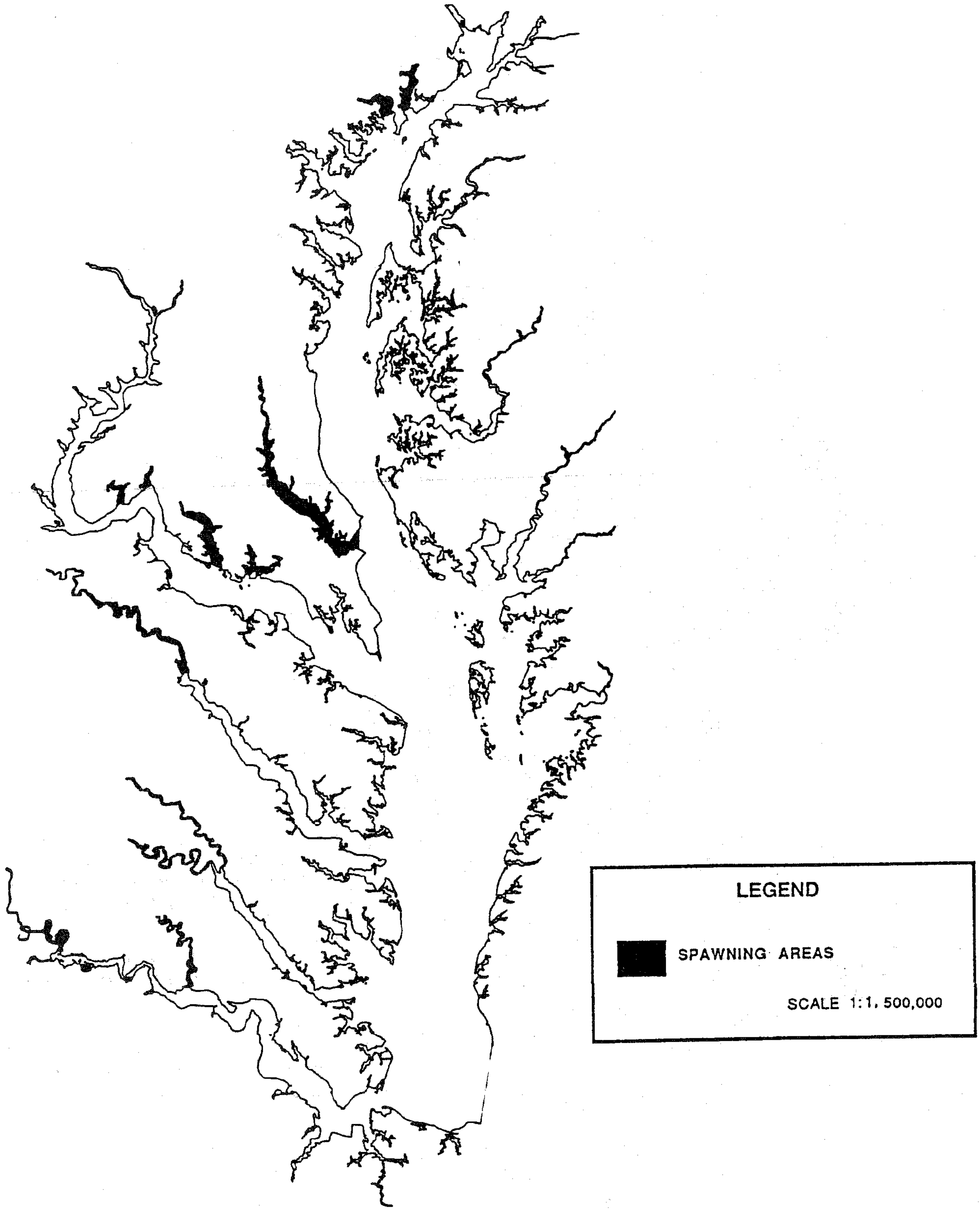
HICKORY SHAD (*Alosa mediocris*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 6

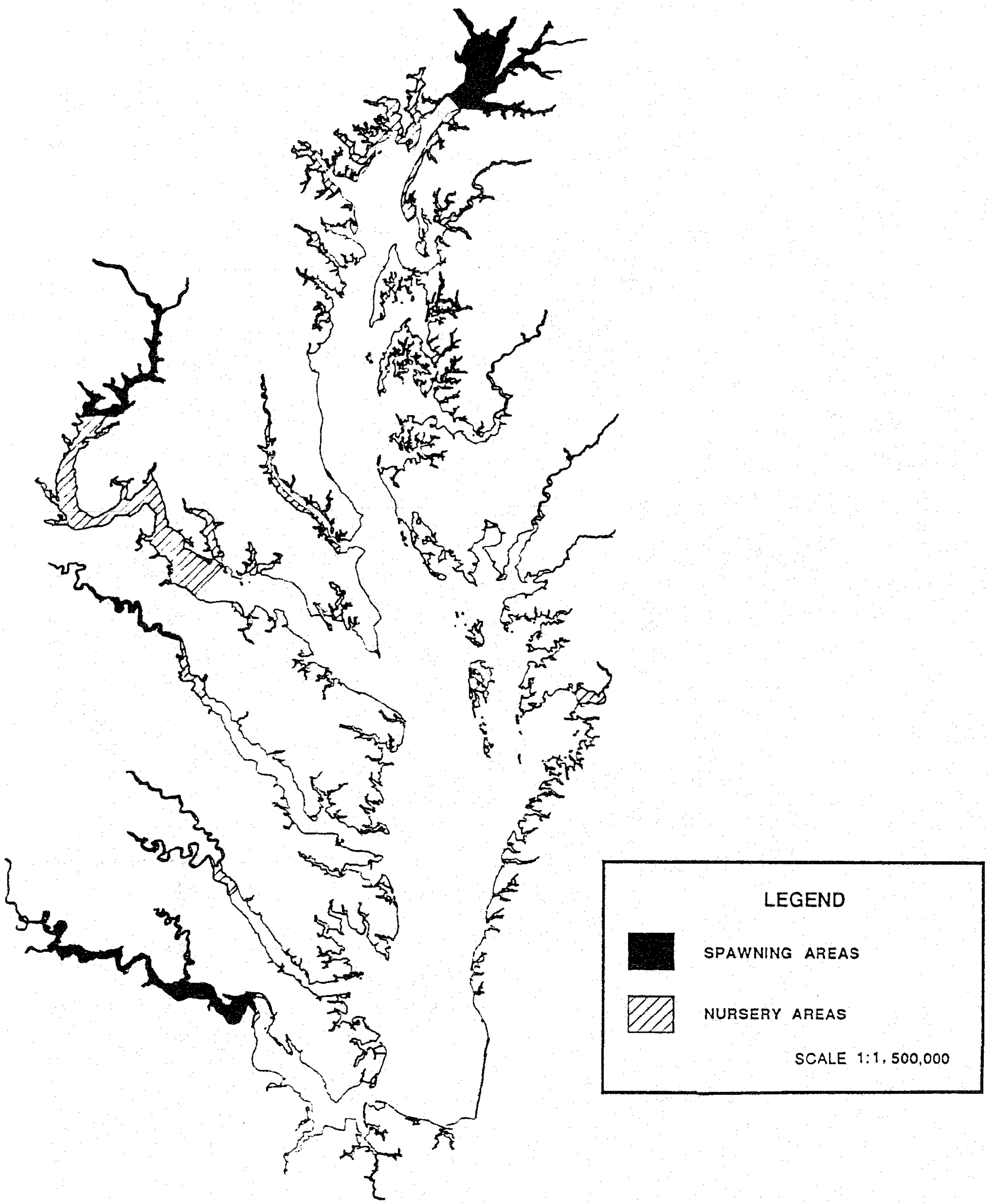
YELLOW PERCH (*Perca flavescens*): HABITAT DISTRIBUTION OF SPAWNING AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 7

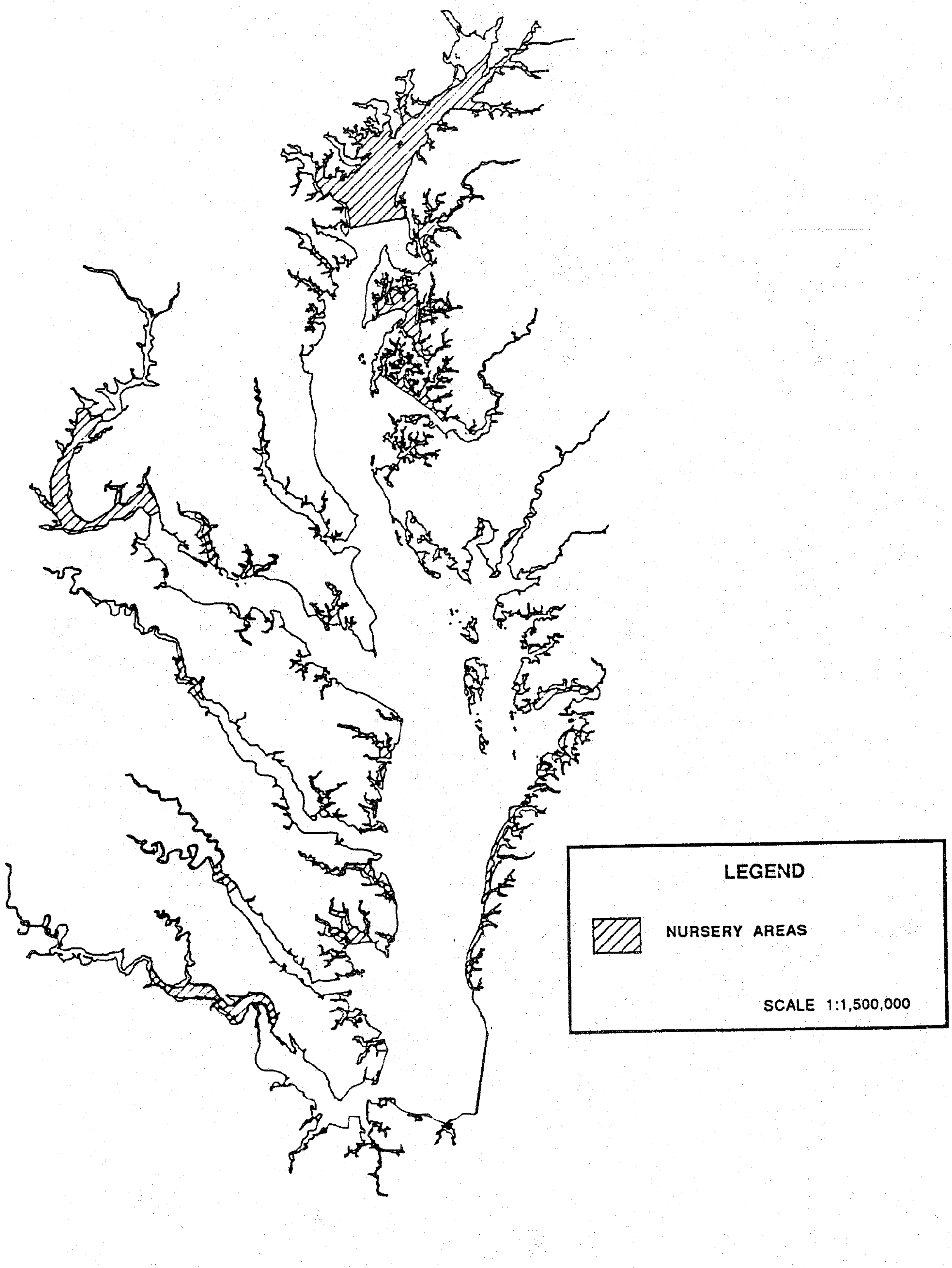
WHITE PERCH (*Morone americana*): HABITAT DISTRIBUTION OF SPAWNING AND NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 8

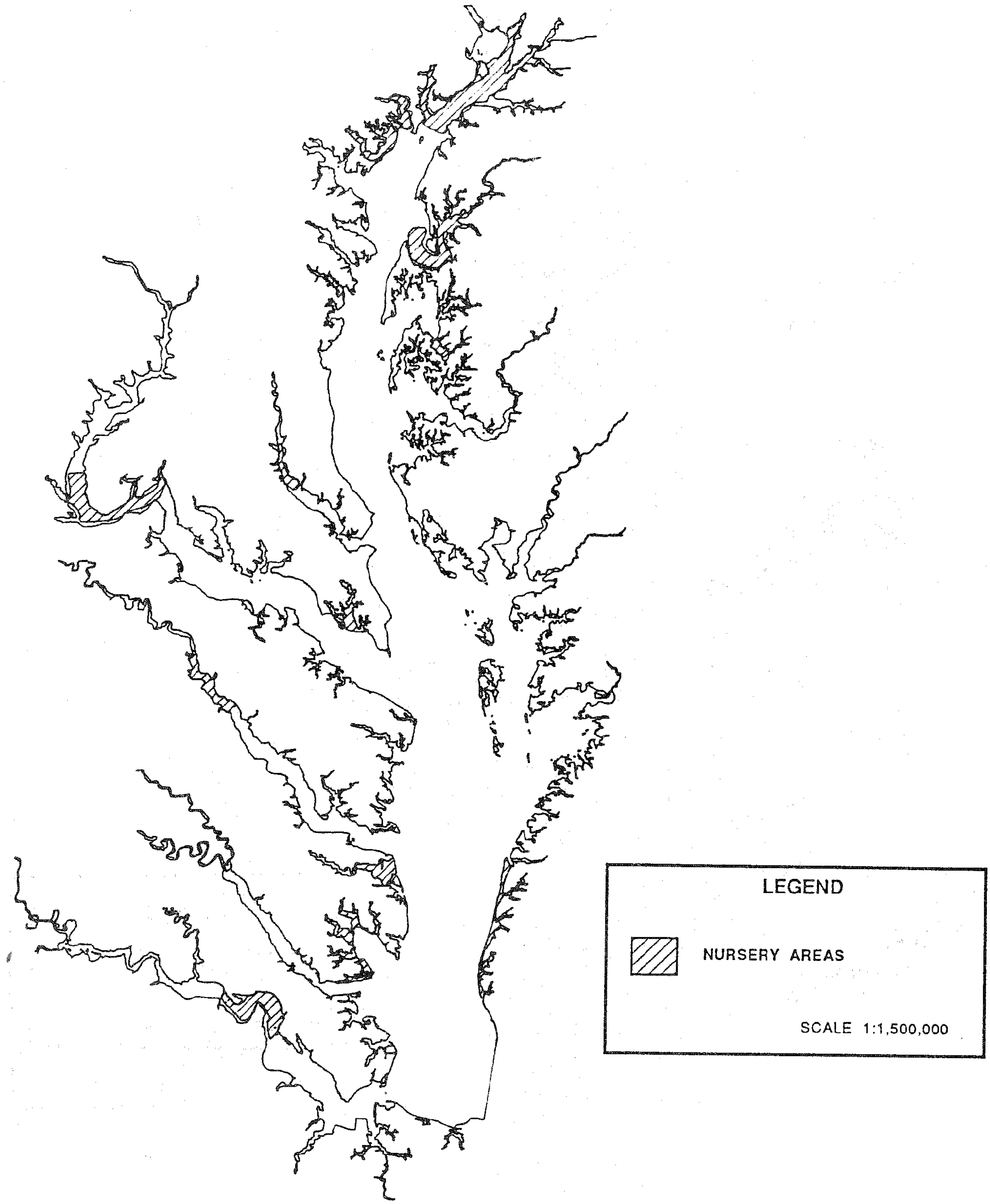
MENHADEN (*Brevoortia tyrannus*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 9

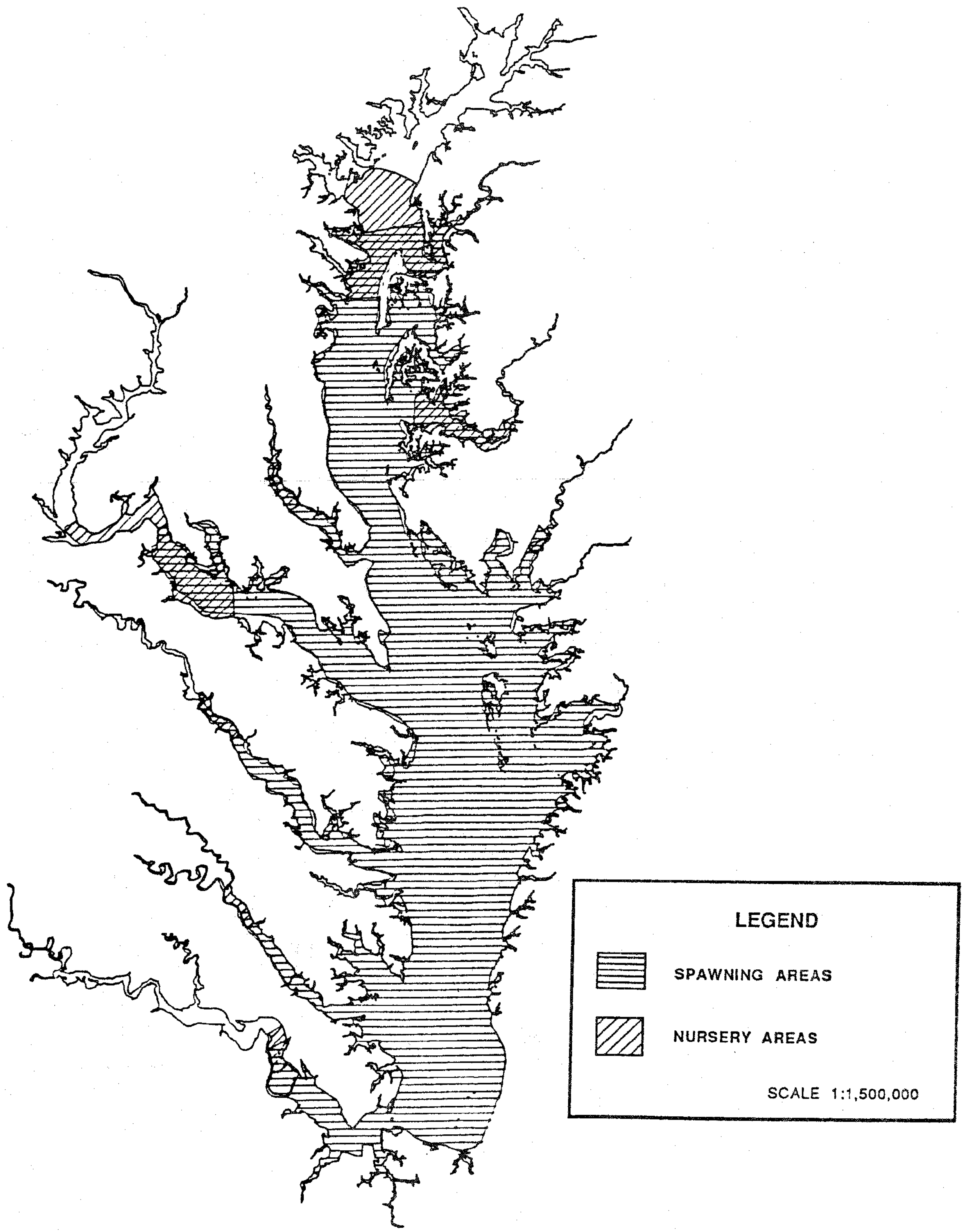
SPOT (*Leiostomus xanthurus*): HABITAT DISTRIBUTION OF NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 10

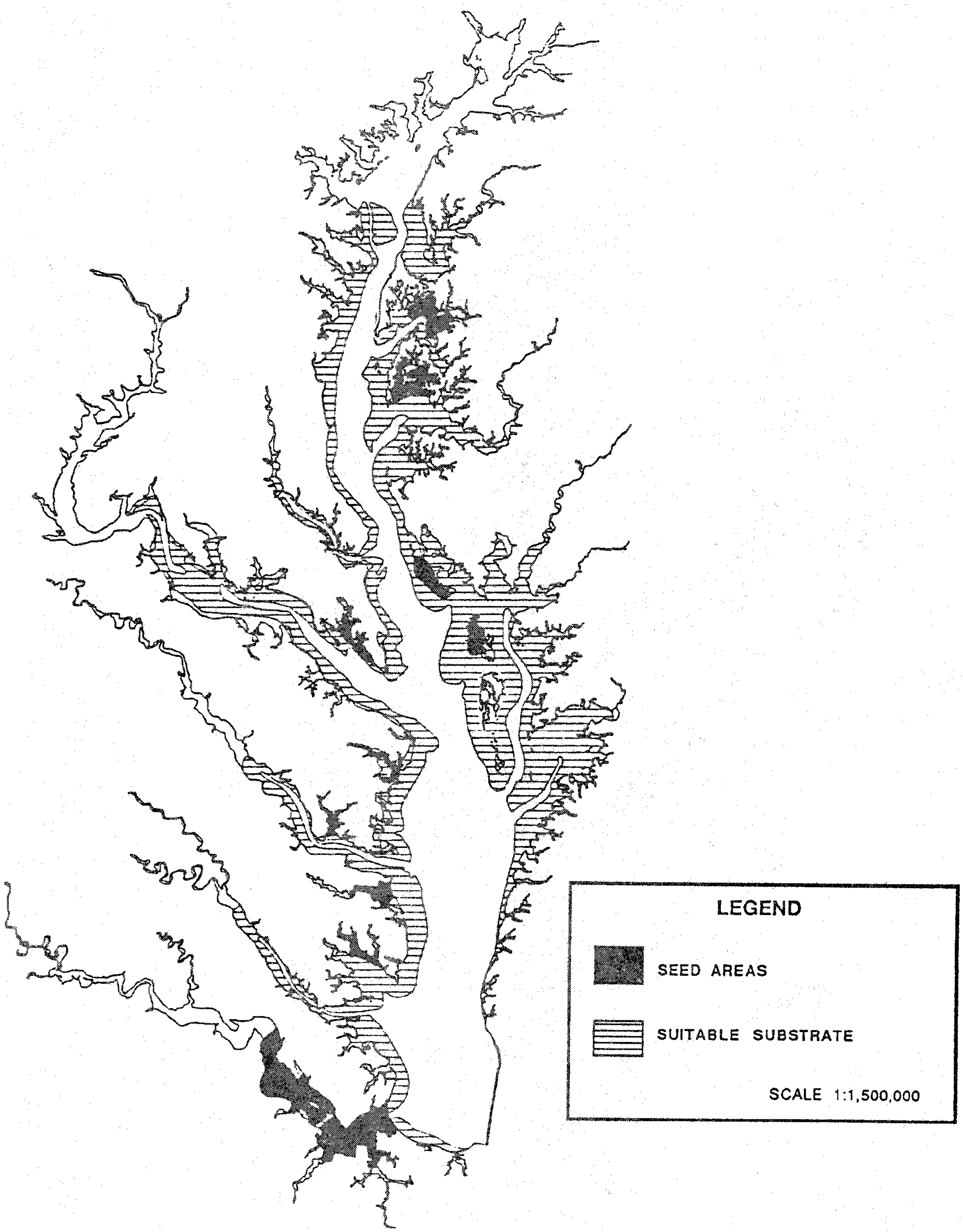
BAY ANCHOVY (*Anchoa mitchilli*): HABITAT DISTRIBUTION OF SPAWNING AND NURSERY AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 11

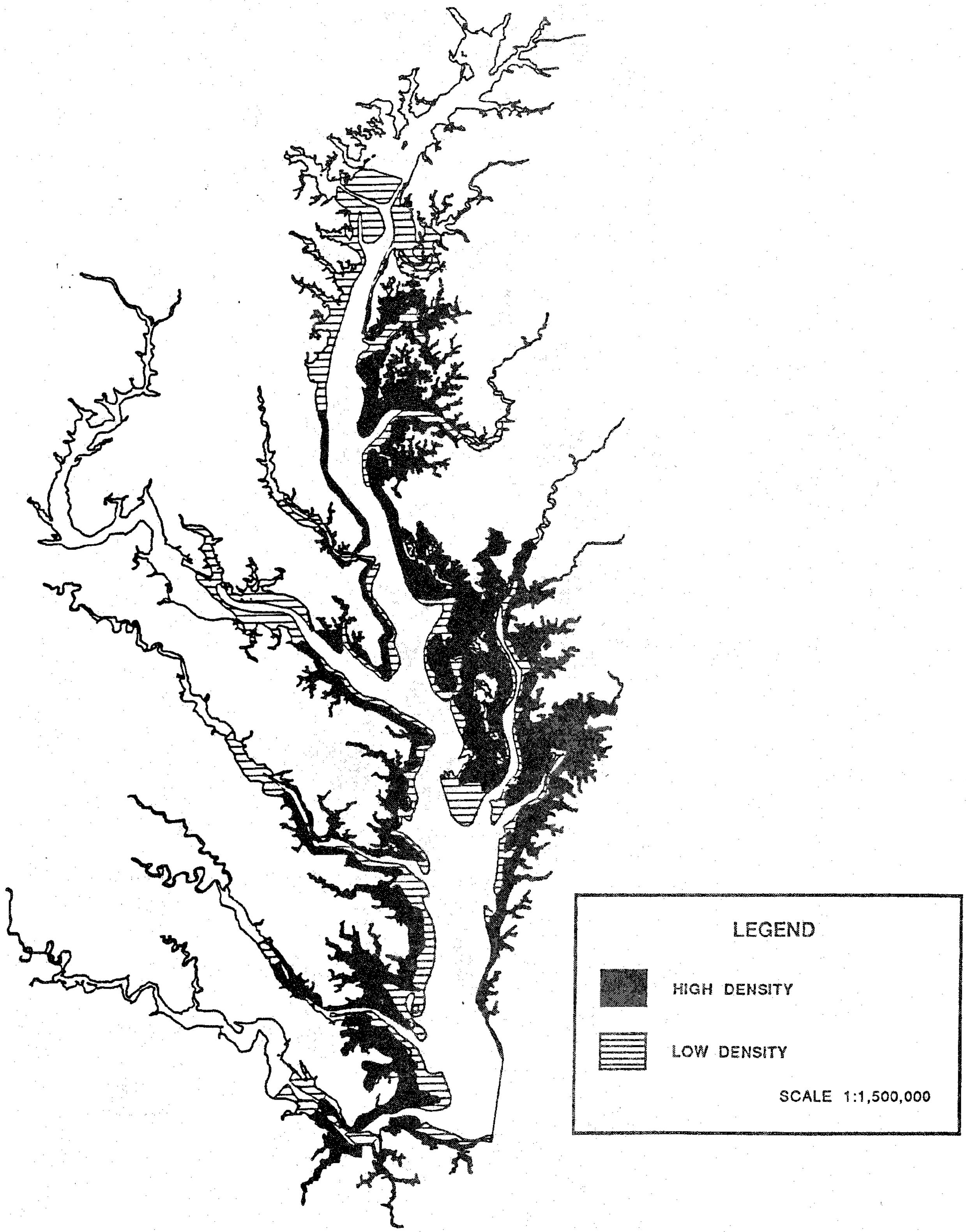
AMERICAN OYSTER (*Crassostrea virginica*): **HABITAT**
DISTRIBUTION OF SEED AREAS AND SUITABLE SUBSTRATE IN
CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 12

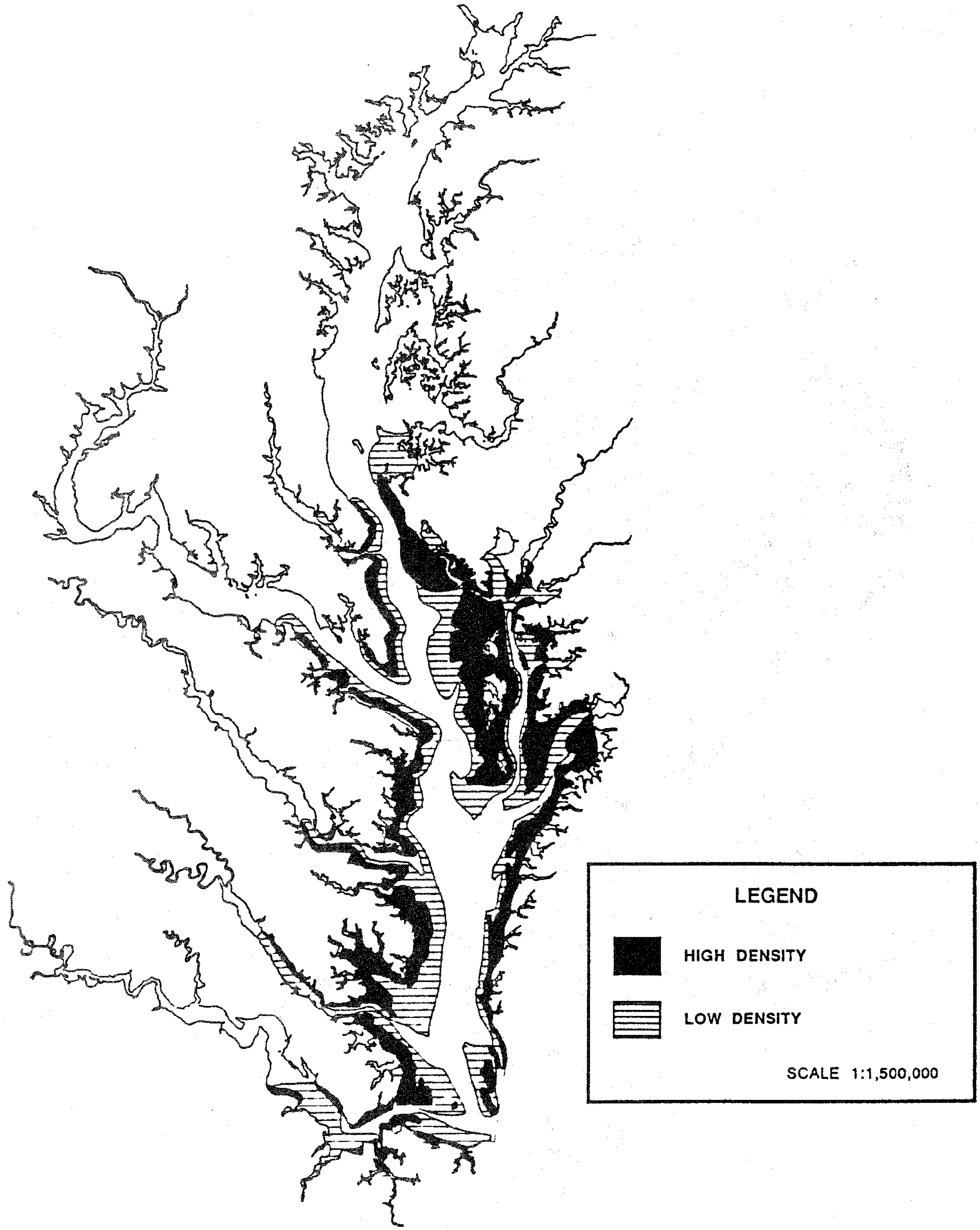
SOFTSHELL CLAM (*Mya arenaria*): HABITAT DISTRIBUTION IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 13

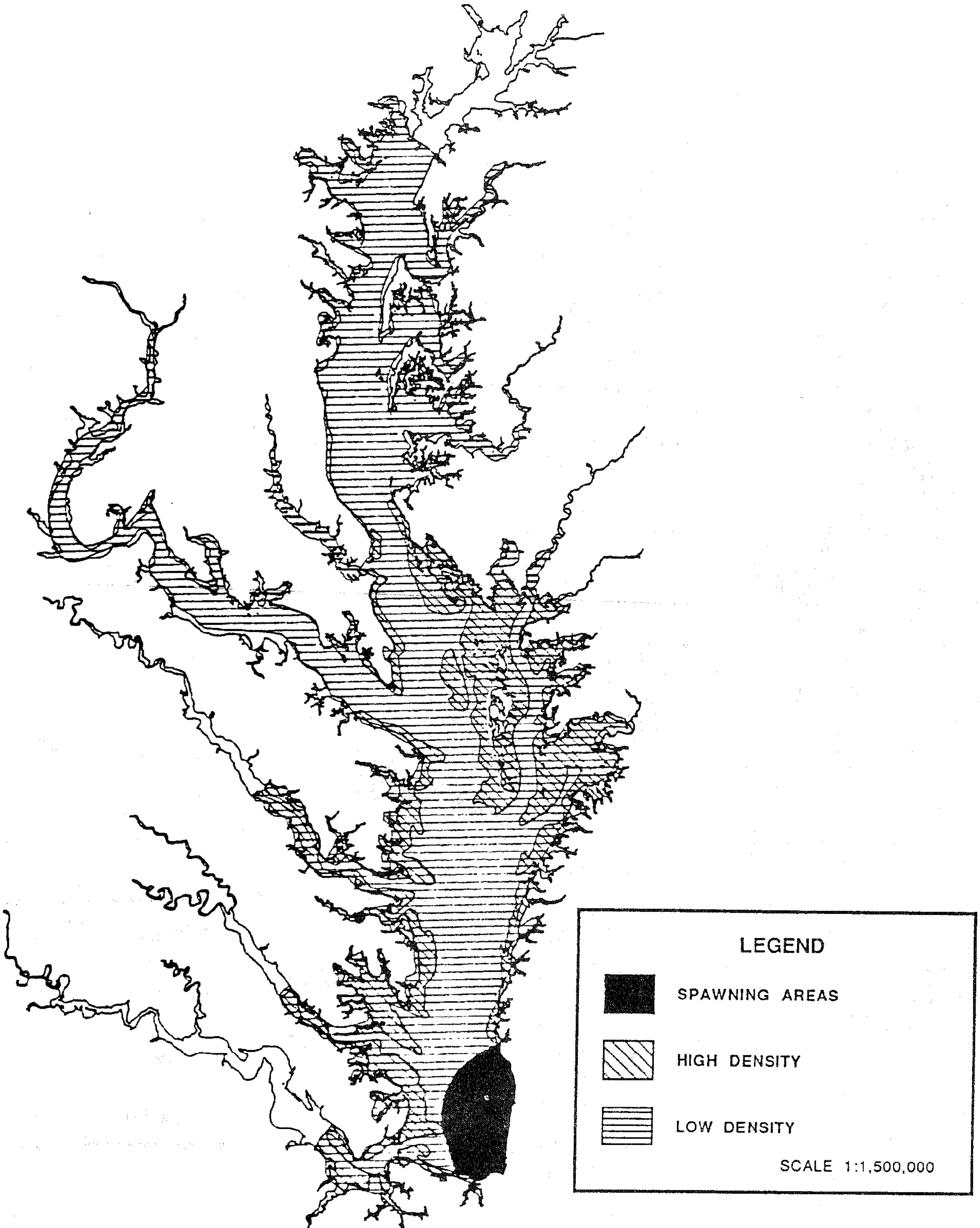
HARD CLAM (*Mercenaria mercenaria*): HABITAT DISTRIBUTION IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 14

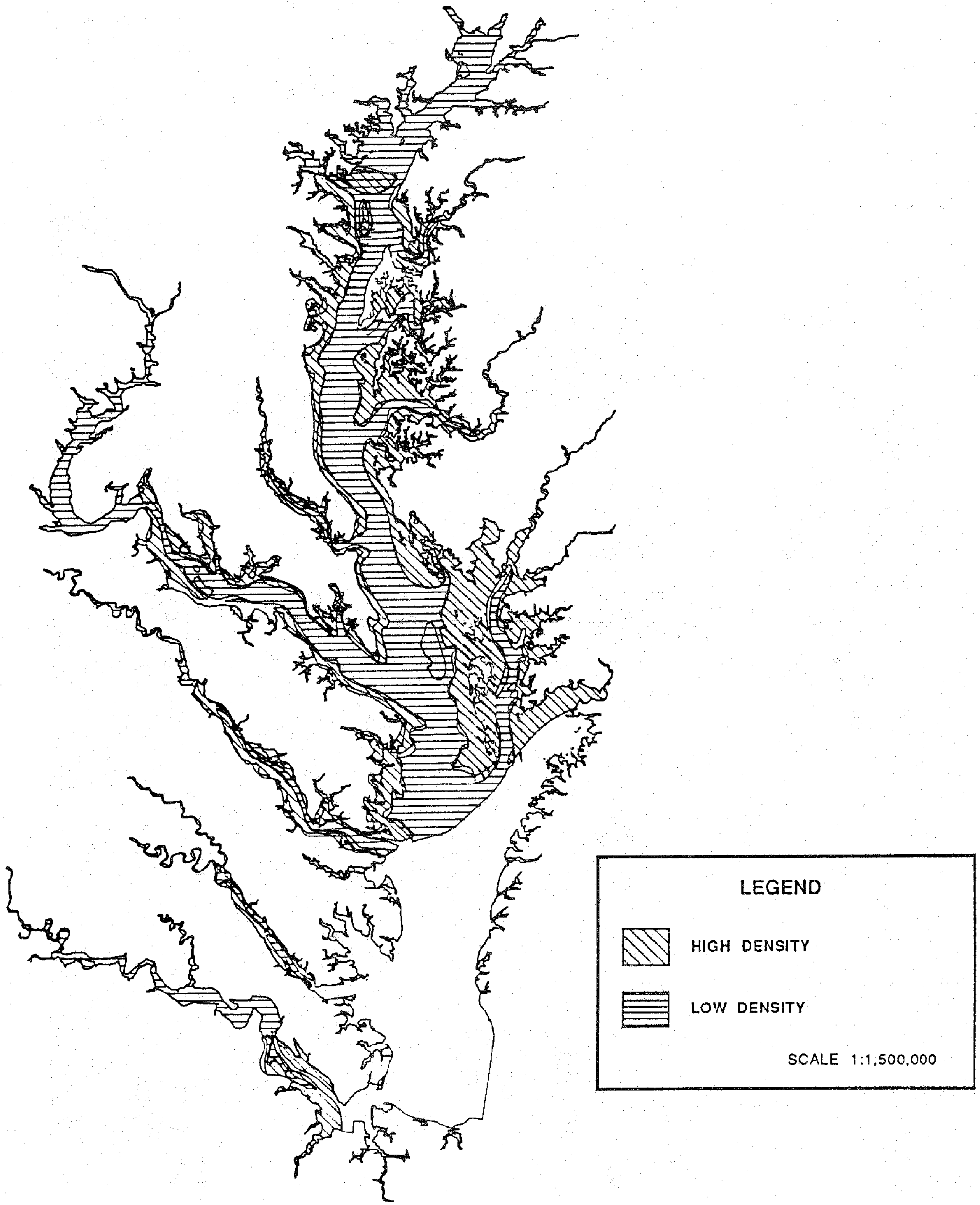
BLUE CRAB (*Callinectes sapidus*) : SUMMER HABITAT DISTRIBUTION OF FEMALES AND SPAWNING AREAS IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 15

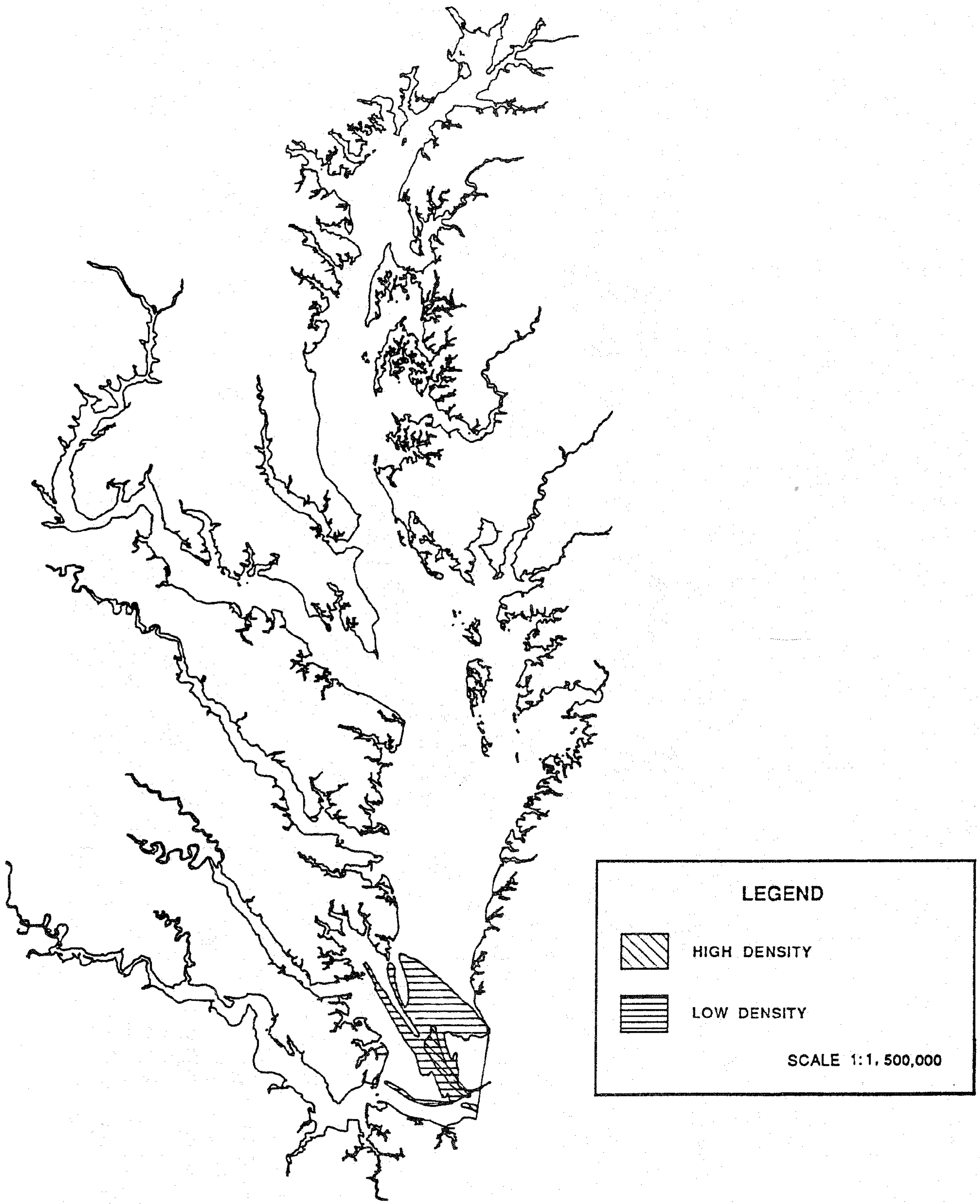
BLUE CRAB (*Callinectes sapidus*) : SUMMER HABITAT DISTRIBUTION OF MALES IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

FIGURE 16

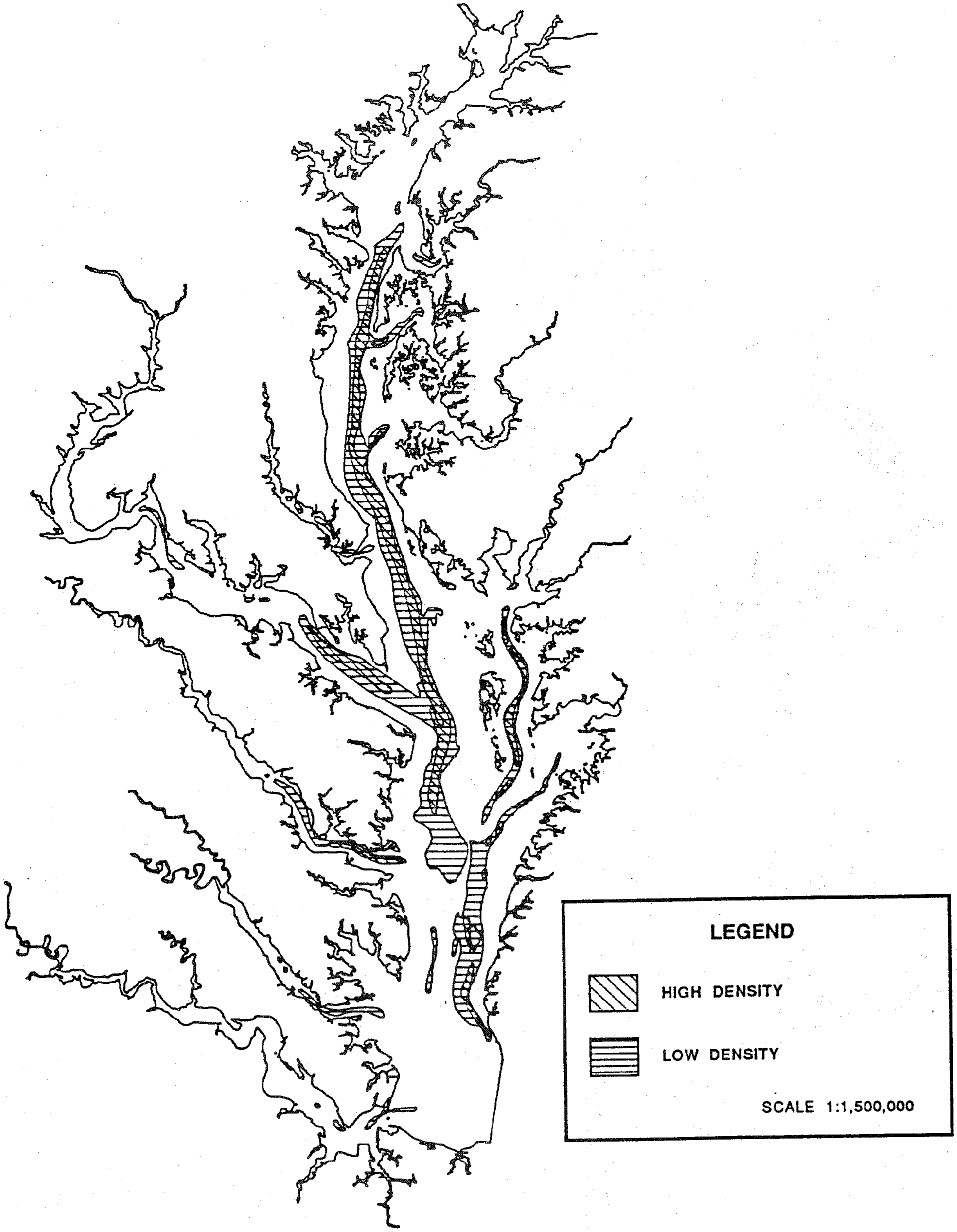
BLUE CRAB (*Callinectes sapidus*) : WINTER HABITAT DISTRIBUTION OF FEMALES IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980

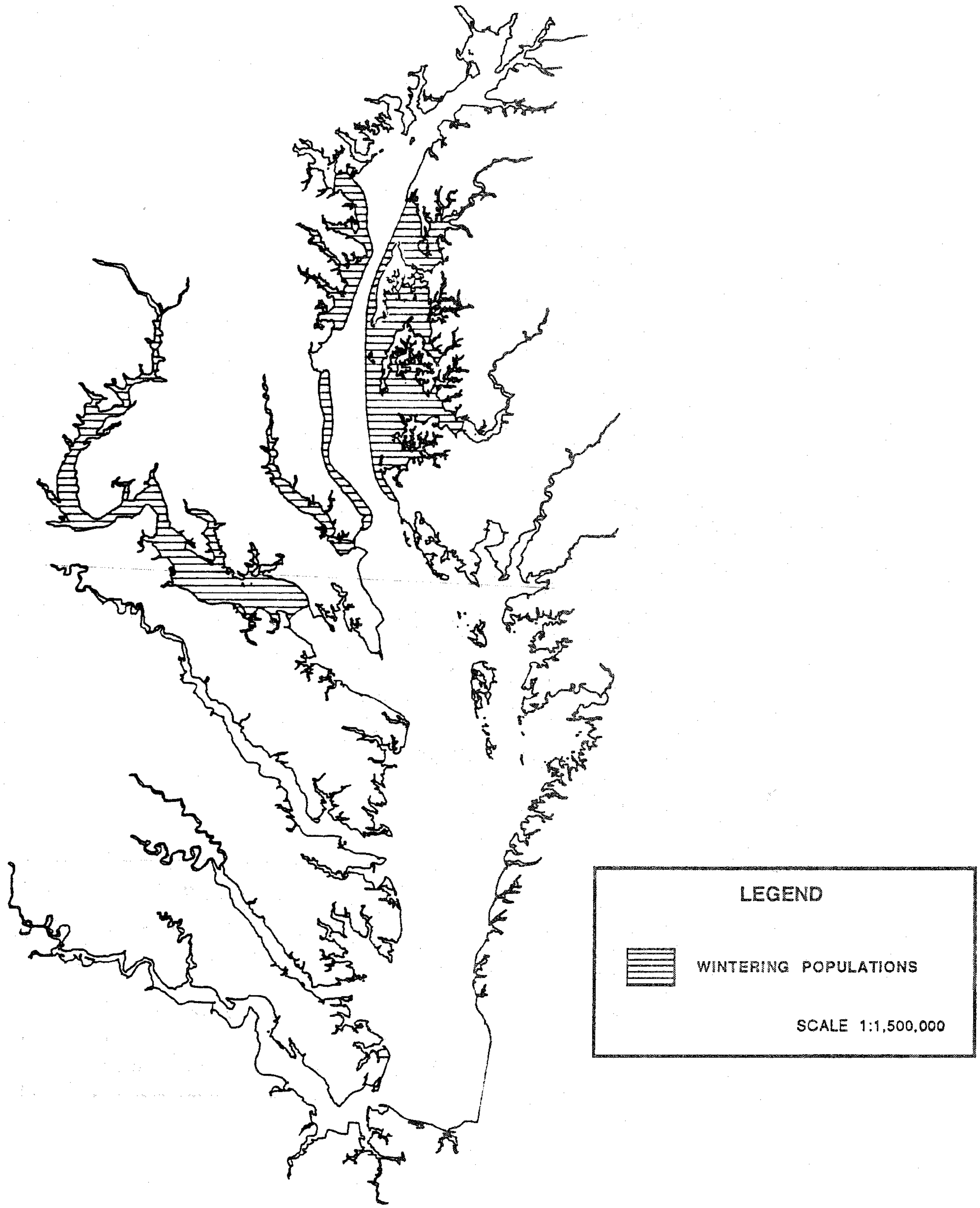
FIGURE 17

BLUE CRAB (*Callinectes sapidus*) : WINTER HABITAT DISTRIBUTION OF MALES IN CHESAPEAKE BAY



SOURCE: Corps of Engineers, 1980 **FIGURE 18**

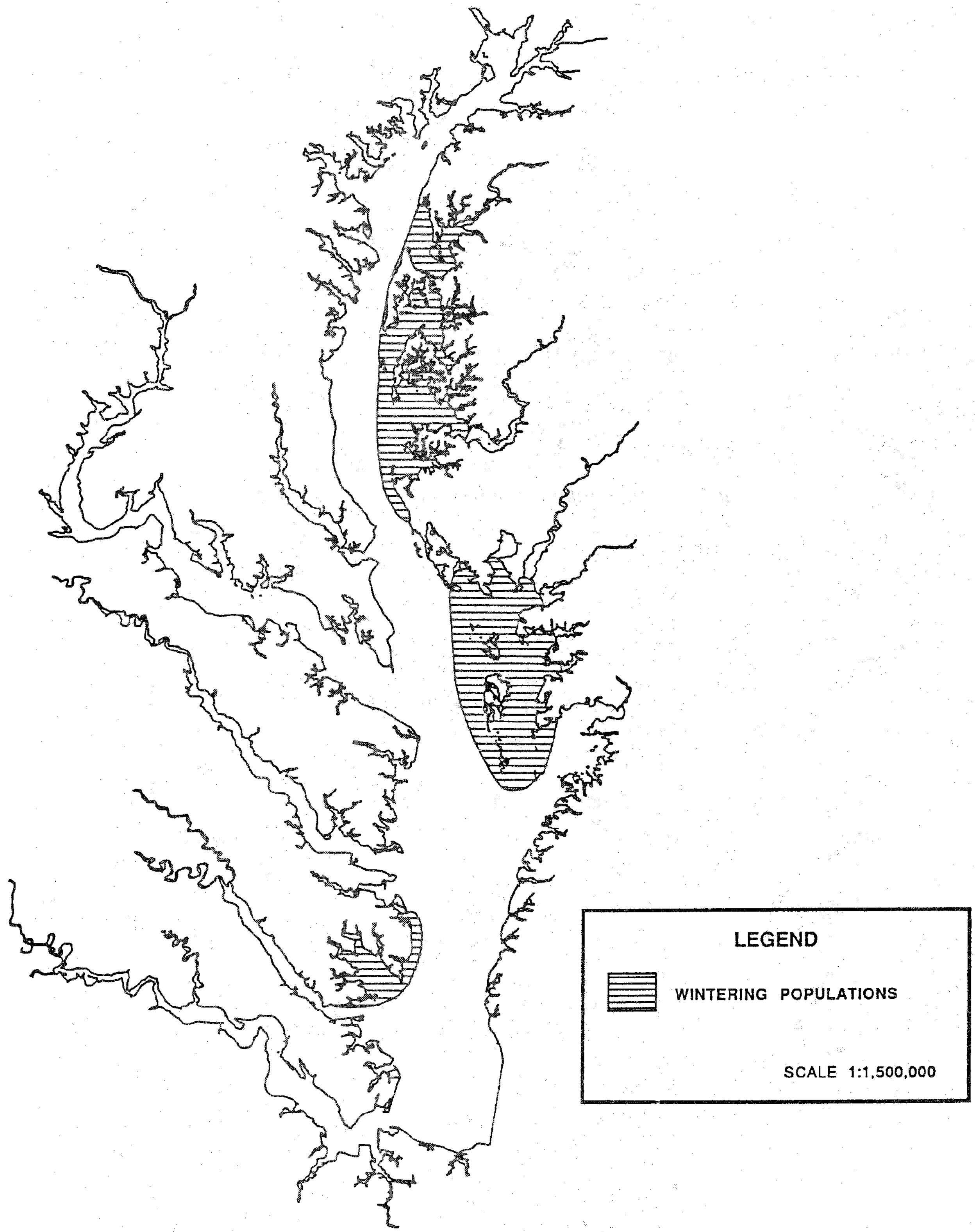
CANVASBACK (*Aythya valisneria*) : DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



SOURCE: USFWS unpublished data

FIGURE 19

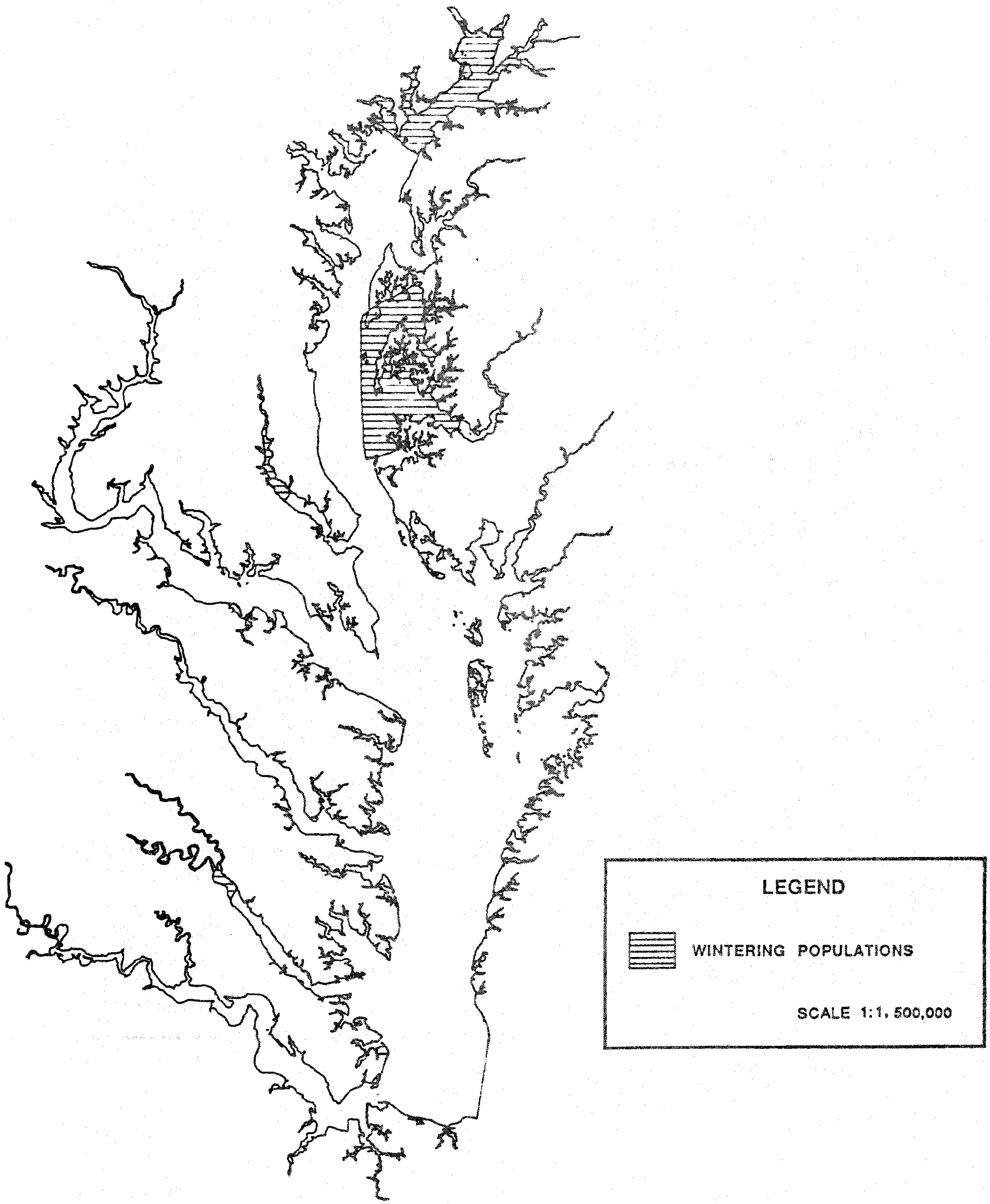
REDHEAD DUCK (*Aythya americana*) : DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



SOURCE: USFWS unpublished data

FIGURE 20

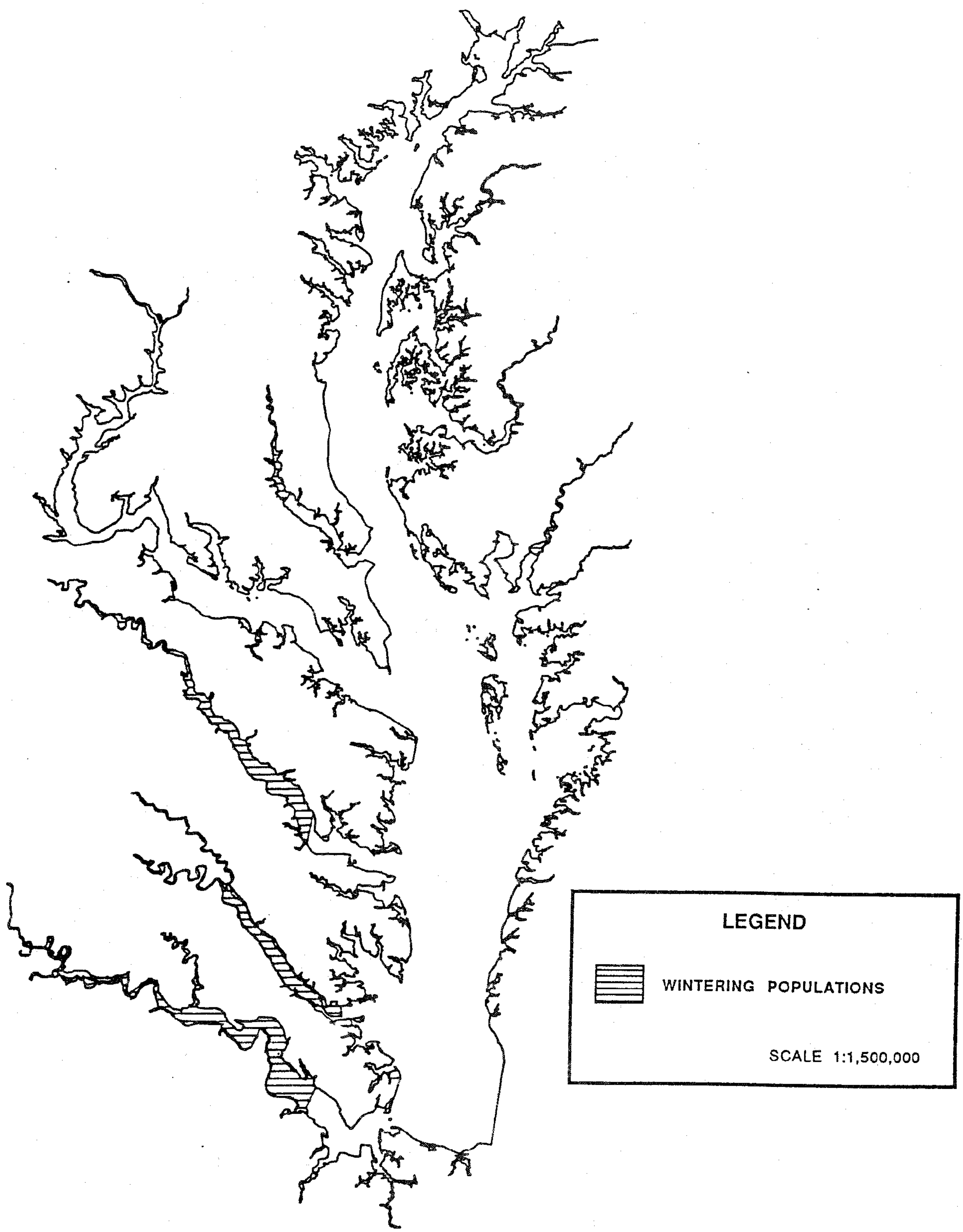
BLACK DUCK (*Anas rubripes*) : DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



SOURCE: USFWS unpublished data

FIGURE 21

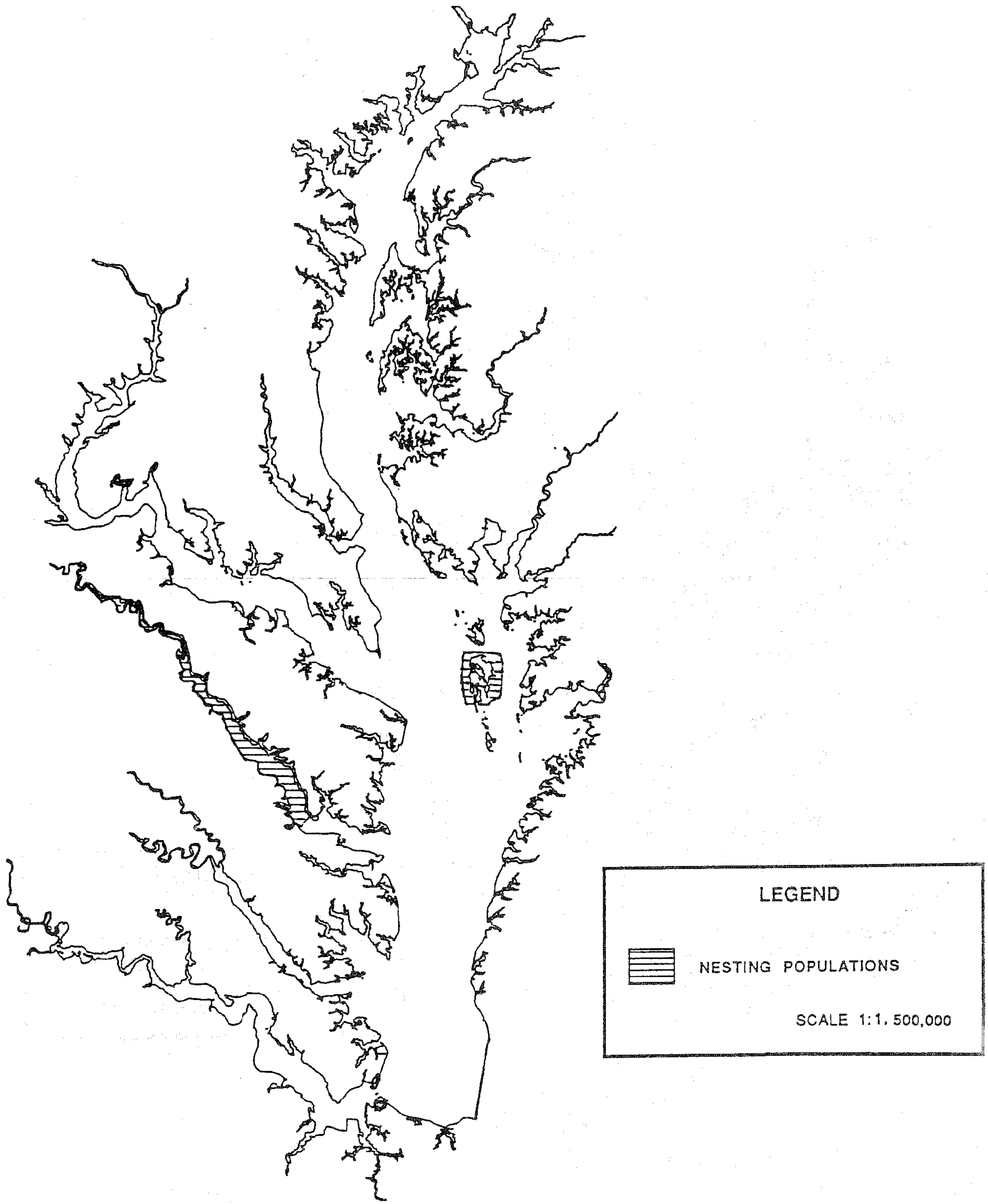
WOOD DUCK (*Aix sponsa*) : DISTRIBUTION OF WINTERING POPULATIONS IN CHESAPEAKE BAY



SOURCE: USFWS unpublished data

FIGURE 22

COLONIAL WATERBIRDS: HABITAT DISTRIBUTION OF NESTING POPULATIONS IN CHESAPEAKE BAY

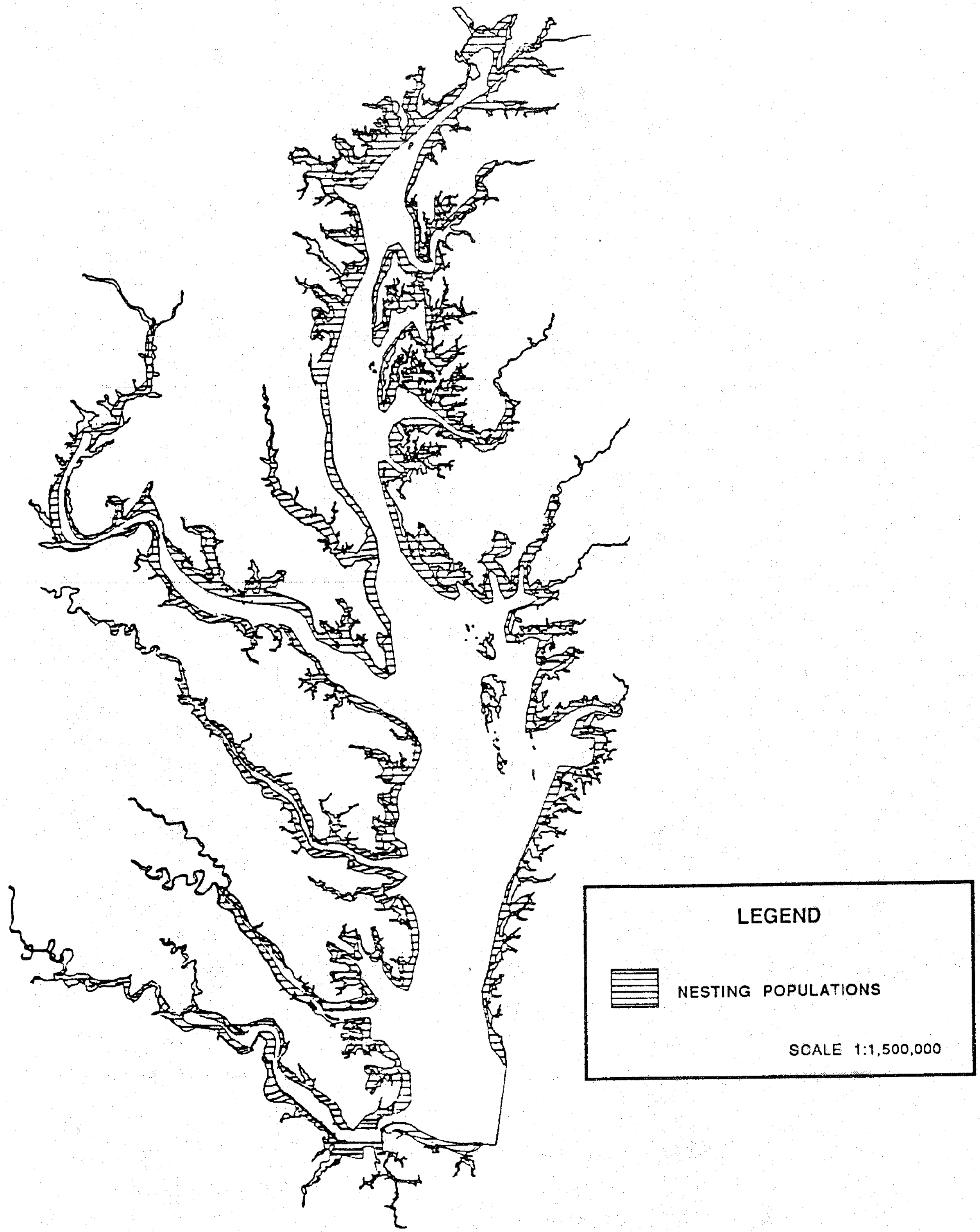


NOTE: Colonial waterbirds include: Great blue heron (*Ardea herodias*); Little blue heron (*Florida caerulea*); Green-backed heron (*Butorides striatus*); Snowy egret (*Egretta thula*); American or great egret (*Casmerodius albus*) Scattered nests may occur in many other wooded, secluded areas of Bay tributaries.

SOURCE: USFWS unpublished data

FIGURE 23

OSPREY (*Pandion haliaetus*) AND BALD EAGLE (*Haliaeetus leucocephalus*): HABITAT DISTRIBUTION OF NESTING POPULATIONS IN CHESAPEAKE BAY



NOTE: Bald eagle nests, roosts and feeding areas are generally found within one mile of the riverine and estuarine shoreline in the Bay system. Occasionally, lakes and reservoirs are used. Some bald eagles remain in the Bay area year round.

SOURCE: USFWS unpublished data

FIGURE 24

APPENDIX C:

REPORT ON THE WORKSHOP ON HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES

United States Environmental Protection Agency
CBP/TRS 8/87

July 1987

Report of the Workshop on Habitat Requirements for Chesapeake Bay Living Resources

Chesapeake Bay Program

REPORT OF THE WORKSHOP ON HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES

Annapolis, Maryland
February 24, 1987

Prepared by:

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Submitted to:

Chesapeake Bay Program's
Living Resources Task Force

FINAL REPORT
May 29, 1987

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PREFACE

Finfish, shellfish, waterfowl and submerged aquatic vegetation have declined in the Chesapeake Bay. Initial Bay restoration efforts have focussed on improving water quality. However, there has been growing recognition that the living resources themselves may be the best guides to developing a strategy for their recovery.

In 1986, the Chesapeake Bay Implementation Committee established a Living Resources Task Force of managers and scientists from Federal and State regulatory and resource agencies, private industry and universities. The Task Force was charged with the goal of developing a resource-based approach to defining water quality and habitat objectives for restoring and protecting living resources in the Bay. These objectives would provide a framework for priority planning and development during and following Phase II of the Chesapeake Bay Program.

Through a series of meetings, the Task Force members developed the following approach to setting resource objectives:

- They identified key representative species in Chesapeake Bay. (Species were selected based on commercial and recreational importance, declining populations and/or importance to the Bay ecosystem.)

- They established priorities for immediate action among these species.

- They identified the critical life stage of each Priority I species within the Bay (i.e., the portion of the species' life cycle thought to be most susceptible to environmental conditions in Chesapeake Bay habitats and the stage that would most benefit from restoration efforts).

- They developed, in matrix form, habitat requirements for critical life stages of Priority I species. The matrices included environmental and anthropogenic factors (e.g., salinity, temperature, toxics concentrations) affecting the key species as well as the major subordinate species required for food or cover.

The matrices were combined into a document called "Strawman II: Living Resources Habitat Requirements for Chesapeake Bay." Where possible, the matrices included specific criteria thought to be protective of the key and/or subordinate species. Although not themselves enforceable, these criteria could be used to provide guidance in setting regulatory water quality standards.

Approximately 60 scientists reviewed the Strawman II document at a one-day workshop on February 24, 1987, in Annapolis, Maryland. This report presents the results of that workshop. In the morning, the participants divided into six planning sessions: Benthos, Plankton, Submerged Aquatic Vegetation, Shellfish, Finfish and Waterfowl/Birds. Following these sessions, participants split into four technical work groups: Finfish, Molluscan Shellfish, Crabs and Waterfowl/Birds.

In the planning sessions, participants discussed the general habitat requirements for species within the associated trophic level. In the technical work groups, participants reviewed the habitat matrices and developed recommendations for enhancing and refining the matrices. At the end of the workshop, the chairmen gave brief reports on the achievements and recommendations of their groups.

This report, divided into seven sections, summarizes the proceedings of the workshop. Each section presents the recommendations and conclusions of a planning session and/or work group (sessions and groups that dealt with the same species have been combined). The workshop agenda, list of participants and a list of Living Resources Task Force members are presented in Appendices A, B and C respectively. Appendix D presents the revised habitat requirement matrices for target species and supporting trophic food species. Appendix E is an addendum to the report of the benthos planning session. Finally, Appendix F lists general comments on the habitat requirements matrices approach.

1. BENTHOS PLANNING SESSION

The Benthos Planning Session was chaired by Dr. Fred Holland, of Versar ESM Operations. The conclusions of the group are presented in this section. Following the workshop, Dr. Holland submitted an addendum, included as Appendix E, that provides more detail on the planning session report.

Benthic communities are an integral part of the food web of Chesapeake Bay and serve an important role as habitat formers. Benthic organisms actively change the nature of the Bay habitat through such processes as bioturbation, nutrient remineralization and structural modification. They directly affect water quality through interaction with sediment and water. That direct interaction makes benthic communities more sensitive indicators and integrators of overall water quality (particularly dissolved oxygen levels) than direct measurement of water quality. They can also indicate relative sediment quality, and are easily collected and enumerated.

Much of the upper Bay benthos (especially deeper portions) is stressed, and is characterized by shallow burrowing, high productivity and rapid turnover. The upper Bay benthic communities have changed from filter feeding to predominantly deposit feeding.

Fish and other predators affect the recruitment of benthic organisms. The upper Bay benthic communities tend to consist of small, fast-growing organisms with high turnover rates. These species may not be the preferred prey for fish and waterfowl (Holland, 1986). Abundances of estuarine benthic species have been increasing since 1970 (though this may not be true for the benthic community in deeper waters) (Holland et al., 1984).

Habitat criteria can be defined for the benthic community; however, synergism among the parameters must be considered. For example, tolerance to salinity may change as temperature changes. At the extremes of an acceptable range, organisms become very intolerant. The matrix approach in the Strawman II document does not consider potential synergism between various habitat parameters.

The group pointed out that it is important to define management goals for benthos. Managing for benthic production would imply a eutrophic (but not polluted) system, whereas managing for a variety of species would require a different approach.

Session participants felt that it would be easy to identify the groups of benthic species that are representative of various specific habitats along the Bay. However, they had difficulty with the concept of establishing water quality parameters based on a critical life stage. The group felt that it was more appropriate to manage for population success as a whole than for the the success of any individual part of the population. Participants pointed out that there may be different critical life stages in different regions of the Bay for the same organisms.

In addition, some participants noted that fish eat many different kinds of benthic organisms. Thus, it makes more sense to identify water quality parameters that will protect benthic organisms as a whole than to do this on an individual species basis.

Following the workshop, Dr. Holland submitted an additional paragraph for the Benthos Planning Session Report:

Over the last several decades the character of Chesapeake Bay benthic communities has changed. Filter-feeding benthic organisms, including oysters and shoft-shelled clams, have generally become less abundant, and small, rapidly growing deposit-feeding species have become more abundant. Recent increases in the abundance of deposit-feeding benthos appear to be associated with long-term changes in Bay water quality, especially increased nutrient levels and algal productivity (Holland et al. 1984). As algal productivity has increased so have organic detritus inputs to bottom habitats. This detritus is the preferred food for deposit-feeding benthos. Because benthic organisms are important prey in the diets of commercially and recreationally important fish and waterfowl, recent changes in the character of benthic communities may be one factor contributing to recent declines in abundance of some fish species (e.g., white perch and striped bass) and increases in abundances of other (e.g., spot). Small, rapidly growing deposit feeders are a suitable prey for spot but may not be as suitable for striped bass or white perch.

2. PLANKTON PLANNING SESSION

2.1 Introduction

The Plankton Planning Session was chaired by Dr. Kevin Sellner, of the Benedict Estuarine Research Laboratory. The participants produced the following report.

As the basis for further discussion, the group agreed that the Chesapeake Bay is a plankton-based ecosystem. Therefore, plankton, as the food source for production of critical life stages of the "key species," control overall fish and shellfish biomass in the Bay. The Strawman II document considered plankton primarily as supporting food chain habitat components of "key species." Session participants recommended that the process for developing habitat requirements emphasize that the Bay is a trophic system where all organisms are inextricably linked to the plankton. The group suggested that plankton control of "key species" production implies that plankton are the <u>key</u> organisms in the system. Factors that control fluctuations in plankton numbers, sizes and production (including circulation patterns in the Bay and tributaries) are critical to the success or failure of "key species." Therefore, the Task Force should consider "key species" production from the lowest trophic levels up, rather than from the top predators down.

In this endeavor, the Plankton Planning Session offered four hypotheses for control of "key species" production to be considered by the Living Resources Task Force.

2.2 Hypotheses

a. Metazoan Food Web

Production of "key species" in the Strawman II document considers classical food web theory, i.e., that fish and shellfish production is a result of a metazoan food web (simplistically, carbon transfer from phytoplankton to copepods to fish). The planktonic food web of Chesapeake Bay includes a microbial-based web as well as the classical metazoan food web implicit in Strawman II food chain requirements. There is growing evidence that a combination of factors - probably arising from synergistic effects of point and nonpoint source additions of nutrients (eutrophication) and toxics - may be resulting in high bacterial production and an abundance of small phytoplankton taxa. A well-developed microbial food web, including high densities of small microzooplanktonic suspension feeders, is associated with high oxygen demand, loss of aerobic habitats and, possibly, an altered food web that would reduce production in the highest trophic levels (key species).

b. Impact of Key Species on Plankton Dynamics

Several pelagic taxa overlooked in the Strawman II document consume large quantities of plankton, leaving less planktonic substrate for "key species" production. The impact of the bay anchovy (the most numerous Bay fish) and ctenophores/jellyfish on plankton dynamics should be considered in potential production of the "key species" listed in the Strawman II document. Bay anchovy affect the system because they may consume large portions of the available plankton prey, diverting much of the carbon away from the key species. Ctenophores and jellyfish are major consumers of zooplankton prey and larval fish in the system.

c. Effect of Nutrient and Toxics Loadings

Chesapeake Bay plankton respond most rapidly to subtle changes in nutrient and toxic loadings from anthropogenic or environmental sources in the watershed. These changes may include alterations in the size and species composition of plankton communities from "normal" assemblages characteristic of the system. Increased production of the perturbation-selected taxa may divert carbon away from key species by modifying classic trophic linkages, possibly contributing to lower production of "key species." Thus, it is important to focus management decisions on the control of anthropogenic inputs that will alter normal "suites" of plankton.

d. Correlation of Larval Stages with Plankton Density

Maximum survival of larval stages of "key species" should be correlated with highest densities of microzooplankton (20 to 200 micrometers) and mesozooplankton (greater than 200 micrometers) in the Bay.

2.3 Conclusion

Chesapeake Bay is a phytoplankton-based system. Any initiatives favoring selective growth of a "healthy" phytoplankton assemblage will maximize potential production of desirable living resources (key species) in the Bay.

Data are needed on the carbon demand for critical life stages of key species in order to estimate whether plankton populations are adequate to support these species. Data are also needed on the selectivity of key species at their critical life stages: Do they prefer certain size or species of plankton? Do they require a specific food quality for proper development, e.g., high protein, high lipid, high carbohydrate? Data are also needed on the temporal and spatial distributions of all plankton types and the critical life stages of the key species of the higher trophic levels.

The overall recommendation of the Plankton Planning Session is that, since plankton are the "key" to Bay fish and shellfish production, the Task Force should concentrate on environmental and anthropogenic factors that control availability of plankton for estimating the success of critical life stages of "key species" in the Bay.

3. SUBMERGED AQUATIC VEGETATION PLANNING SESSION

3.1 Introduction

The planning session was chaired by Dr. Court Stevenson, Horn Point Environmental Laboratories. The group determined that submerged aquatic vegetation (SAV) can be divided into three groups that have different water quality requirements: plants in high salinity areas (e.g., *Zostera marina* and *Ruppia maritima*), plants in mid-salinity (*Potamogeton pectinatus*, *Potamogeton perfoliatus*, *Ruppia maritima* and *Zannichellia pulustris*), and plants in low salinity to tidal freshwater (*Hydrilla verticillata*, *Heteranthera dubia*, *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Vallisneria americana*).

3.1.1 High Salinity

The high salinity environments in the lower Bay tend to be more nitrogen-limited. When nitrogen concentrations are high, algal growth is a problem for SAV. Dense phytoplankton blooms shade submerged aquatics as well as promote algal epiphytes which can form dense colonies on the leaves. The current view is that epiphytic and epifaunal overgrowth can weaken submerged aquatic populations by limiting primary productivity through shading, thus depleting carbohydrate reserves. If substantial carbohydrate energy is not stored throughout the winter in subsediment, roots and rhizomes, growth of SAV will be adversely affected in the spring. If algal epiphytes continue to overgrow the plants for several years, this can cause a decline in SAV, as observed in the late 1970s.

Both nitrogen and phosphorus seem to stimulate SAV growth in the high salinity region when applications are made in the root zone.

3.1.2 Mesohaline

The mesohaline environment has a gradient of nutrients, with high levels at the heads of estuaries to relatively low levels at the midpoint of the Bay. There has been a resurgence of SAV growth in recent years, particularly in the mesohaline areas with elevated salinity levels. Data indicate that SAV populations may decline indirectly due to overenrichment at average summer concentrations in the water column of greater than 0.14 mg/l dissolved inorganic nitrogen and greater than 0.01 mg/l phosphate. Thus, levels of less than 0.14 mg/l dissolved inorganic nitrogen and less than 0.01 mg/l phosphate may be suitable for use in defining areas that will support SAV growth in brackish waters. These values appear to be thresholds at which epiphytic overgrowth becomes problematic to SAV. Light conditions in the mesohaline portions of the Bay are often limiting, particularly in the summer. The group recommended (1) that attenuation coefficients should not exceed a Kd of 2 (photosynthetically active radiation - 400 to 700 nanometers); (2) that levels of suspended solids in the water column levels should be less than 20 mg/l, and (3) that chlorophyll a in the water column should be less than 15 μg/l.

3.1.3 Freshwater

Substantial regrowth of freshwater SAV has occurred over the last several years in tidal fresh portions of the Potomac. This is probably due in part to the reduced nutrient loading from the Blue Plains wastewater treatment plant, which caused decreased algal growth, hence less shading in the water column and via epiphytes. Also, low runoff in 1985 and 1986 caused decreased nonpoint-source nutrient loadings which appear to have increased SAV growth. Participants felt that the current regrowth was an excellent natural experiment that should be analyzed further to provide data on the relationship of nitrogen and phosphorus levels to SAV growth.

There can also be substantial SAV growth at the head of the Bay in high nitrogen concentrations (in the range of 0.7 to 1.4 mg/l) as long as phosphorus concentrations are very low (less than 0.01 mg/l). SAV can grow in part because the low phosphorus inhibits algal growth, and the SAV can obtain phosphorus from sediments. However, some SAV species may create high enough daytime pH levels to activate release of phosphorus from sediments, thus causing algal blooms. This mechanism may be partially responsible for the high pH in the Potomac estuary.

3.2 General Comments/Recommendations

Light intensity in the Bay is less than it has been historically, and it was felt that a return to pre-Agnes (i.e., prior to June 1972) levels was a worthwhile goal. One source of information for these levels is Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System (Davis et al., 1976).

Nutrients and sediments limit SAV more than low salinity. Phosphorus is an important limiting factor, particularly for epiflora in shallow freshwater. Nitrogen could also be an important factor in higher salinity areas. It was pointed out that nutrients must be considered together, and that nitrogen as well as phosphorus should be considered in management decisions on reducing nutrient inputs to the estuarine portions of the Bay.

At present, data indicate that metal concentrations in Chesapeake Bay sediments are not high enough to be toxic to SAV. Submerged aquatics can sequester metals in their tissues and serve as indicators for past pollution episodes.

Herbicides do affect SAV. Widely used herbicides such as atrazine may have local effects on submerged aquatics in shallow embayments that are affected by agricultural runoff. It was tentatively agreed that levels less than 10 ppb would not present a problem in open waters. The journal literature does have information on specific herbicide levels that impact particular SAV species.

Pesticides do not appear to harm SAV directly, but they do adversely affect invertebrates and heterotrophic food chains; thus potentially harming SAV. For example, pesticides may adversely impact snails (*Bittium* sp.), which usually clean epiphytes from leaves. Declines in snail populations could cause reduced photosynthesis for the plants.

The group agreed that transplantation of submerged aquatic plants provides an excellent environmental measurement of existing water quality. These transplantation efforts should be closely monitored to elucidate the relationship between water quality and continued reestablishment of SAV.

As much new literature on SAV has been published recently, the group recommended that the comprehensive literature review conducted by Dr. Stevenson (Stevenson and Confer, 1978) be updated. The U.S. Fish and Wildlife Service is considering funding this.

Participants recommended that increased emphasis be placed on habitat monitoring of water quality, particularly in the more shallow SAV beds. This monitoring would serve to document continuing changes in water quality in an effort to define population requirements in various sections of the Bay.

A report being prepared by Court Stevenson and Lorie Staver for the Maryland Department of Natural Resources Tidewater Administration will provide information on water quality parameters associated with the resurgence of submerged aquatic vegetation in the mid-Chesapeake. The report will be available in July 1987.

4. SHELLFISH PLANNING SESSION AND TECHNICAL WORK GROUP

4.1 General Approach and Recommendations

The planning session and technical work group were chaired by Dr. Roger Newell, Horn Point Environmental Laboratories. Reports from both groups are combined within this chapter.

Participants agreed that many estuarine species of bivalve are similar in their tolerance of certain environmental parameters, e.g., suspended solids, dissolved oxygen. Therefore, the group developed comments and recommendations for each parameter that would generally apply to all molluscan shellfish. Separate criteria should be developed only when there is a real difference in response between species, e.g., substrate type. The similarities between species mean that creating conditions that are favorable to one species will generally benefit other species.

Participants recommended that interactions between parameters be considered. They cautioned that single factor analysis would never be sufficient. For example, an animal might be unaffected by one factor alone but synergism or the additional sublethal stress provided by a second may result in a reduction of fecundity or larval viability.

The group commented that it was unrealistic to try to restore the Bay to its former condition, i.e., that existing prior to colonization by European settlers. Instead, emphasis should be placed on resource management to try to retard the accelerated pace of change to the system and explore enhancements of fishery habitats in more localized areas. Further discussion and consideration are necessary to establish a desirable and realistic goal for mollusc population size.

4.2 Geographic Distribution

Participants recommended that management goals should aim to expand the range of all species up to their tolerance limits, especially into low salinity regions. This would require limiting harvest pressure in the low salinity areas. Where possible, sanctuaries should be maintained in marginal habitats. This might help to provide a reserve of individuals that would be available to colonize the more optimum habitats. The optimum habitats should also be preserved and managed to help modify the effects of fishing pressures.

The group considered the importance of diseases (e.g., *Haplosporidum nelsoni* [MSX] and *Perkinsus marinus* [dermo]) and predators in controlling the oyster population and distribution. Although these factors cannot be controlled at present, they do regulate geographic distribution of species. Natural factors, including diseases, predators and climatic variation, have a much greater influence on oyster populations than anthropogenic and environmental factors that can be controlled by management practices. This should be taken into account when making management decisions.

Commercial harvesting has changed the oysters' habitats. Dredging and overharvesting have spread out or reduced the height of the reefs. The reefs are now broader and have much less relief above the sediment and are, therefore, more susceptible to sedimentation processes.

4.3 Critical Life Stage and Period

The group agreed that both the larval and adult life stages for clams and oysters are critical life stages, and that each stage is susceptible to different stress factors.

4.4 Habitat Requirements

Food (Including Chlorophyll, Nitrogen, N/P Ratios and Carbon)

The Strawman II document gave different food requirements for different species. Participants felt that this could be simplified since all bivalves have very similar food requirements. The group noted, however, that there is a critical food size for different life stages. (The group discussed the importance of involving phytoplankton experts in developing a strategy to manage the environment so as to maximize the production of 3- to 35-micrometer (diameter) cells that bivalves feed on. The group suggested that it was important to understand how any changes in the patterns of primary production that may be occurring in Chesapeake Bay affect all life stages of the molluscs (see Section 2.1).

Rather than separately consider major food species, chlorophyll, nitrogen, N/P ratios and carbon, participants considered them together as a single food requirement. The group recognized the complexity of factors affecting primary production and concern with the statement made by the Plankton Planning Session (see Section 2.1). They cautioned that, for some criteria, size must be considered to ensure availability to the animal. For example, chlorophyll in cells smaller than 3 micrometers will not be available to the animal; thus a total chlorophyll measurement could be deceptive. Chlorophyll measurements should, therefore, be partitioned into the appropriately sized fractions.

Substrate, Suspended Solids, Turbidity, Secchi Depth and Light Intensity

The group agreed that sedimentation (including substrate, suspended solids, turbidity, secchi depth, and light intensity) is an important habitat factor influencing the continued propagation of shellfish. Members felt that the principal factor affecting the success of the oyster in Chesapeake Bay is the lack of clean cultch. Clean oyster shells (cultch) are the preferred substrate for oysters, and oyster larvae require a clean shell for settlement and metamorphosis. However, factors such as heavy harvesting and disease are causing a decline in the preferred substrate. An active oyster bar is not subject to siltation because it extends into the water column where currents carry away biodeposits and silt. However, once the bar has been compromised (e.g., by overharvesting and high sedimentation rates), the system shifts from a filter-feeding system to a deposit-feeding system. It then becomes very difficult to return the bed to its former condition. Some participants questioned whether changes in sedimentation rates would have much effect on deposit-feeding systems. The group discussed using sediment trap methodologies to estimate sedimentation in the actual oyster-producing areas. These methods would provide better measures of water quality than turbidity or secchi depth.

Participants stressed that it was important to manage the Bay to reduce loads of suspended particulate inorganic material, especially during the period of spawning and larval settlement. Repropagation of SAV beds in critical habitats would reduce resuspension of bottom sediments but would not prevent deposition through the water column. Adult mobile infaunal clams are not as sensitive to burial by sediments as oysters, but juvenile clams can actually be smothered by siltation.

Participants commented that the Bay is a pulse system with many fluctuations (see Appendix E), and therefore it would be difficult to set a specific level for total suspended solids. The group criticized the sediment-related criterion of

1,000 mg/l as being unrealistic, probably because it was derived from dredge areas rather than the natural environment.

Cover

SAV cover is important in reducing turbidity within the system, thereby maintaining cultch quality. SAV also provides a very important refuge for juvenile clams from crab and fish predation. Reestablishment of SAV could markedly increase production of infaunal clams. Oysters are the most important cover for setting oysters.

Temperature and Salinity

Participants did not attempt to set levels for these parameters. Temperature and salinity fluctuations are normal habitat requirements. Anthropogenic effects on Bay conditions are not significant enough to make these parameters worth considering as a management issue except in local areas, e.g., power plant discharges, which are already strongly regulated. Anthropogenically altered freshwater flow to the estuary might modify both temperature and salinity and should be considered.

Metabolic activity of shellfish is strongly temperature-linked and must be considered in relation to other parameters. Environmental factors are less important in the winter when the shellfish are dormant. Participants noted that larval stages are more sensitive to temperatures.

Flow

Brief salinity fluctuations that result from natural flow patterns may aid the control of parasites and disease (see

Appendix E). Therefore, it might be beneficial to reestablish oyster bars in areas where flow patterns would encourage periods of low salinity.

pH

The group changed this parameter to "6.8 to 8.5," but noted that pH fluctuation is a natural phenomenon and would be difficult to control. pH is lower under anoxic conditions; therefore, steps should be taken to control anoxia. Changes in pH may affect the phytoplankton community, which in turn will affect molluscs.

Dissolved Oxygen

Dissolved oxygen (DO) is critical for all molluscan shellfish life stages. However, the tolerance of anoxia varies with life stage and with season. In the summer, the tolerance is markedly reduced. Participants recommended that the habitat matrices have a seasonality component, and that a matrix of these interactions be developed. Data are needed on how long species can survive under anoxic conditions. Ongoing research as part of the NOAA/Seagrant Hypoxia Program will provide new insights, particularly concerning the effect of low DO on larvae. Lateral movements of anoxic bottom waters over clam and oyster beds and the impacts on these beds should be studied.

Ionic Constituent

The group determined that this parameter is not applicable to molluscan shellfish.

Bacteria

Participants recommended that this parameter be retitled "Pathogens." They discussed the importance of pathogens in controlling geographic distribution (see Geographic Distribution above).

Phosphorus

This parameter is not directly applicable to molluscan shellfish, but could become a factor through the food chain.

PAHs, Metals, Insecticides, Herbicides and Chlorinated Hydrocarbons

The group considered these classes of compounds together. Tributyltin was also mentioned by one participant as being a toxicant of concern. Although there are good data to show that all these compounds can be highly toxic, especially to larval stages, the general consensus was that these compounds may not be that important in regulating production on a Bay-wide basis. The group felt that current efforts to enforce existing toxicant standards should be adequate for protecting oyster and shellfish populations. It is possible, however, that toxicants may pose a problem in local environments where toxicants are discharged into the Bay (e.g., localized use of antifouling compounds). In general, however, toxicants sequestered in shellfish tissue are a human health concern, if consumed, rather than an important influence on shellfish survival.

Participants thought that the metals levels listed in the Strawman II document would protect larvae, and that small molluscs may tolerate even higher levels. The group questioned the criterion of less than 0.0001 ppb for mirex. They asked that this figure be double-checked. Oil in the Sea, Inputs, Fates and Effects (National Research Council, 1985) was cited as a reference for effects of hydrocarbon. Another reference that may be of interest is an NAS report on detergents used to clean up oil spills, to be published in 1987.

Following the workshop, Dr. John Kraeuter (Baltimore Gas and Electric Company) submitted the following statement:

> While specific effects of oil on oysters, hard clams and soft clams have been shown, these data are derived mostly from information collected in conjunction with major oil spills. The effects of oil at low concentrations are not as well known, but developmental processes can be sensitive to petroleum, and even fairly low concentrations can result in measurable abnormalities (less than 1 mg/l). Hydrocarbons also have histopathological and/or mutagenic potential, and concentrations of petroleum as low as 10 ug/l can alter normal behavior of many marine organisms. In view of the National Academy Review, the Shellfish group recommends efforts to reduce petroleum hydrocarbon input to Chesapeake Bay. It would seem this can best be done by controlling outputs in ports, marinas and harbors (boats), runoff from storm drains (streets and roads) and from municipal wastewater facilities.

Hardness and Alkalinity

The group agreed that these parameters are not applicable to molluscan shellfish.

Other Comments

Following the workshop, Dr. Kraeuter submitted a statement on the importance of Bay processes. This is included as Appendix E.

5. FINFISH PLANNING SESSION AND WORK GROUP

This report covers the finfish planning session and technical work group, which considered both anadromous and marine spawning finfish. The sessions were chaired by Dr. George Krantz, Maryland Department of Natural Resources.

5.1 Species List

The planning session began by discussing changes to the list of priority finfish species in the Strawman II document. The changes that participants made to the list are indicated in Table 1. The group thought that the Strawman document should include any ecologically important fish, regardless of their current level of prosperity or commercial or recreational significance. The bay anchovy and killifish were added to the Priority I list because of their ecological importance. The killifish is extremely important for nutrient exchange between the marsh and the higher fish food chain. The hog choaker was added because it is the most pollution-tolerant species and can therefore act as an indicator of degraded environments. Any damage to this species would suggest that the more sensitive species are seriously threatened. (The hog choaker would therefore not be appropriate to use as a basis for modelling or management.) The Atlantic sturgeon was moved from Priority I to II because there are so few of them that participants did not think it appropriate to base management decisions on this species. The croaker was moved from Priority I to II because its population fluctuations are not thought to be directly related to the Bay. The naked goby and oyster toadfish were added to Priority III because they are an important ecological link. Cobia was dropped from the Priority II list because no one in the work group could attest to the importance of this ocean fish to the Bay.

TABLE 1

PRIORITY SPECIES DESIGNATED BY FINFISH WORK GROUP[a]

PRIORITY I	CRITICAL LIFE STAGE FOR PRIORITY I SPECIES	PRIORITY II[d]	PRIORITY III
Striped Bass	Egg Larvae	Weakfish	Red Drum
Alewife/Blueback Herring[b]	Egg Larvae	Largemouth Bass	Black Drum
American Shad[c]	Egg Larvae	**Croaker**	Black Sea Bass
Yellow Perch	Egg Larvae	**Summer Flounder**	Winter Flounder
White Perch	Egg Larvae	**Bluefish**	**Naked Goby**
Menhaden	Juvenile	**Eel**	**Oyster Toadfish**
Spot	Juvenile	**Sturgeon (Atlantic and Shortnose)**	**Spotted Sea Trout**
Hog Choaker	**Egg Larvae, Juvenile**		
Bay Anchovy	**Egg Larvae, Juvenile, Adult**		
Killifish	**Egg Larvae**		
Blueback[b]	Egg Larvae		
Hickory Shad[c]	Egg Larvae		

[a]Species in bold were either added or switched from one priority list to the other by the Work Group. Non-bold species were already present on Strawman II list in the same stated priority.

[b]Important.

[c]Very important.

[d]The work group recommended the Cobia be deleted from Strawman II as a priority species.

5.2 General Changes and Recommendations

Participants agreed that the background information supplied for each species was unacceptable. They recommended that new background writeups be prepared based on A.J. Lippson's Bay Atlas (see Table 2 for reference). They also recommended this reference as a good source of information on geographic distribution. Several other sources were identified which contain species distribution and spawning ground maps, including Habitat Sensitivity maps for Maryland, Corps of Engineers Map Folio, etc. (see Table 2). The group agreed that the terms, categories and citations in the matrix should be clarified.

The "critical life stage" was defined as the period in which habitat variation has the greatest impact on a given species. For each species discussed, the group reviewed the criteria and indicated whether they were critical (i.e., essential to survival), noncritical, or tentatively critical (not of concern at current levels, but potentially critical to survival if present environmental conditions are altered). Participants asked that it be noted in the Strawman document that all the listed habitat criteria have some important biological impact at some level, even though this level may appear extreme compared to present ambient levels. They also noted that negative synergistic effects could become evident at the upper and lower limits for any parameter. Synergistic effects, though not considered in the current matrix approach, could radically alter any fish species response to a specific habitat criterion. For example, hardness by itself is not considered critical, but in combination with low pH and heavy metals, the synergistic effect is fatal. The finfish group felt that synergistic and interaction effects would become more critical when habitat conditions approach the margin of tolerance of any parameter.

TABLE 2

INFORMATION SOURCES FOR FINFISH

1. U.S. Fish and Wildlife Service - Species documents providing habitat suitability curves for individual species (i.e., shad, striped bass) to be used in IFIM.

2. Habitat Suitability Index Documents - Biology Report. National Wetlands Center (formerly National Coastal Ecosystems Team), U.S. Fish and Wildlife Service, Slidell, Louisiana.

3. Atlantic States Marine Fisheries Commission - Management plans for a number of species (those listed as Priority I).

4. U.S. Corps of Engineers (COE) - New England region species-specific biology profiles.

5. Susquehanna River Anadromous Fish Restoration Committee - Restoration of American Shad to the Susquehanna River, 1986 Annual Progress Report. U.S. Fish and Wildlife Service, Harrisburg, Pennsylvania. 340 pp.

6. U.S. Army Corps of Engineers (COE), 1982 - Map Folio: Chesapeake Bay Low Freshwater Inflow Study, Phase II, Biota Assessment. Prepared for the U.S. Army Engineer District Baltimore, by Western Eco-Systems Technology, Inc. 204 215th Street, Bothell, Washington 98011.

7. Virginia Institute of Marine Science Anadromous Fish Project Annual Reports.

8. National Oceanic and Atmospheric Administration (NOAA) Sensitivity Maps: Ann Hayward-Walker of NOAA was mentioned as someone who is updating various species sensitivity maps and atlas information and whose work might be included in the final document.

9. University of Maryland - Baird/Ulanowicz (authors), "Chesapeake Ecosystem Network Documentation."

10. New Orleans Coastal Ecosystem Studies.

11. Ronald Hellenthal's Trophic Information (University of Notre Dame, Department of Biology, South Bend, Indiana 46556).

TABLE 2 (continued)

12. Draft Report on Polynuclear Aromatic Hydrocarbons and the Chesapeake Bay, Maryland Department of Natural Resources, October, 1986.

13. Westin, D. and B. Rogers (1978) - Synopsis of Biological Data on the Striped Bass, *Morone saxatilis* (Walbaum) 1792. Univ. of Rhode Island Marine Tech. Report 67.

14. A.J. Lippson (1973) - The Chesapeake Bay in Maryland: An Atlas of Natural Resources. The Johns Hopkins University Press, Baltimore and London. 55 pp.

The group worked through the matrices for the striped bass, alewife/blueback herring, and Atlantic menhaden and spot, and established criteria for the critical life stage of these species. Participants did not try to establish an optimum range for the Priority I species' critical life stages. Rather, members tried to establish a criterion level or range that would ensure no adverse effects. They agreed that it is important to set criteria based on what the fish need, not what habitat conditions they currently survive in. Thus, in some cases, current data may be inappropriate.

Participants strongly recommended that all criteria that might not be relevant to the fish population of interest be deleted from the Strawman document. They asked that the preamble state that the values given represent the extremes for protecting species; i.e., habitat conditions should never exceed the criteria. Participants were very concerned about the potential for misuse of criteria; i.e., criteria could be taken as allowable levels for degradation rather than limits to protect species.

Much information in the literature was not in the matrix. Since no single definitive source document exists, the group recommended that several additional documents be attached to the Strawman document to provide background information on the elements of the matrix (see Table 2).

After working through the first two species, participants found that some parameters were generic to specific groups of finfish in similar trophic levels. They discovered that all the matrix elements influence trophic dynamics, and therefore supported the conclusions of the plankton work group. Conceptually, management of the habitat for fishes must include all parameters that sustain intermediate trophic levels and near ideal conditions.

Within the matrices, several changes were suggested. The "Bacteria" criterion should be changed to "Pathogens." The "Zone" criterion should be specified as "Vertical Zone," since horizontal zone is covered by geographic distribution. The "N/P Ratios" criterion should be placed next to the "Nitrogen" and "Phosphorus" parameters in the matrices. "Chlorine" should be added as a critical variable to all matrices. The group suggested that, if the tables are to be used for management decision-making, they should exclude all factors that are uncontrollable by existing management techniques, although a number of parameters (i.e., flow, temperature) can be critical to survival and can be affected by development, dams, industry, etc.

Several habitat parameters can be treated generically. Biological systems in fish have similar basic requirements and, therefore, similar responses to most environmental features. Participants did not set any levels for nitrogen and phosphorus for any species, but requested that the following points be noted concerning these parameters: Ammonia, nitrites and any form of reduced nitrogen are known to be toxic. Nitrogen and phosphorus can have direct toxic effects on finfish, but the most critical impact is their collective effect on food production and anoxia in stratified waters. These factors must be taken into account when setting levels for these parameters for finfish.

Temperature, pH and dissolved oxygen could be treated generically with a few minor exceptions by species or by geography of species. Habitat levels of 6.5 to 8.5 for pH and greater than 5 mg/l for dissolved oxygen were felt to be acceptable as generic criteria.

Metals, PAHs, chlorinated hydrocarbons, herbicides and pesticides were combined for all Priority I species. The group decided that levels that would have no adverse impact on the most sensitive species in this group (the alosid) should be used for all species in the absence of species-specific data. Again, the philosophy was stressed that levels should be set so that there is no biological impact. The group stated that the levels set should minimize the possibility of intertrophic magnification or additivity of toxic chemicals as a result of chronic exposure. However, the bay anchovy and killifish are more tolerant so criteria could be higher for these species. The Interstate Fisheries Management Plans of the Atlantic States Marine Fisheries Commission (ASFMC) were cited as a source for data on these parameters (ASMFC, 1985; Atlantic Menhaden Management Board, 1986). Data from the Draft Final Report on Polynuclear Aromatic Hydrocarbons and the Chesapeake Bay (Maryland Department of Natural Resources, 1986) suggest that fish experience lethal effects when exposed to 12 ppb PAHs.

Following the workshop, Dr. Krantz submitted the following statement regarding the matrix approach:

> Relationship between fish habitat and their population success must follow closely the concept of the weakest link in the chain of life. The matrix exercise has focused on critical criteria and may be missing the concept that if any single habitat criterion is violated, the chain, with all its intact critical links, would still be broken. Though often difficult to comprehend, this concept is essential and must be considered in planning. Two very important axioms must be considered.
>
> First, one adverse experience in the life cycle of a fish population can be critical. For example, transit phenomena, which are of very short duration (minutes), can destroy the chain at any point over the course of the entire life cycle of a fish species. For mathematicians, this means that averages cannot be used, only the extreme of the numerical distribution. This is the reason the group suggested upper and lower incipient levels for responses.
>
> The second axiom is that habitat parameters for finfish must also include the most constraining value for every other component of the trophic ecosystem. The critical chain of life with its weak links also runs vertically

through the trophic levels that are used to describe biomass or energetics (nitrogen, phosphorus, and carbon). These components must be passed successfully through the pyramid to the higher trophic level occupied by fish. A diminution of a lower trophic level (algae, zooplankton, worms) would have an adverse impact on the higher trophic level. What escapes many scientists and the lay manager or planner is that a small change in a lower trophic level is multiplied by each trophic level that a contributing trophic component is passed through. For example, a very small change (e.g., a 10 percent change in this example) in an algae species that is consumed by a food chain that reaches the fifth trophic level of a given fish species is technically raised a minimum of five times when its impact is ultimately expressed in fish biomass. This means that we could expect a potentially large change (e.g., a 50 percent change in this example) in fish biomass from a 10 percent change in an important algae trophic component. Unfortunately, the human element focuses on commercially or recreationally important species. We have failed to realize that insults to the lower trophic level organisms are magnified by passage through the food chain. This phenomenon alone could explain the demise of many of the Bay's fish species. Therefore, all habitat criteria that have a detrimental effect on any trophic level should be described as negative factors in this matrix exercise. These negative factors may not fit the matrix format now being used for fish if they occur in another trophic level. If a lay manager focusses only on fish, he or she will fail to detect critical criteria in other trophic matrices.

5.3 Matrices

Matrices were filled out for three species: striped bass, alewife/blue herring and Atlantic menhaden. The above consensus point, that information on the alosids provides protection to all species, evolved by comparing the results of these three species to all others.

5.3.1 Striped Bass

Background. Dr. Krantz recommended the Guidelines for Striped Bass Culture (Bonn et al., 1976) as a source of background information. In addition, the group compiled a list of nine references on the striped bass (see Table 3). Grant and Olney (1982), Grant and Olney (1981) and Olney et al. (1983) provide patterns of abundance of eggs and larvae in the James, Pamunkey, Mattaponi, and Rappahannock rivers. Tresselt (1952), Massmann et al. (1952, 1962), Rinaldo (1971) and Merriner et al. (1980) provide additional documentation of spawning activity.

Critical Life Stage. The critical life stage was expanded to include both larval and juvenile stages.

Critical Life Period. The critical life period for the striped bass was discussed. The group agreed that the critical life period for larval and juvenile stages is April to June.

Food. Prey was not discussed for any species.

Substrate and Cover. The group decided these parameters were not applicable to the critical life stages of the striped bass.

Zone. Zone was changed to "water column, demersal."

Salinity. Salinity was reduced to "0 to 5 ppt" for the critical life stages.

Flow. The group agreed that flow is a critical parameter and reduced it to "0 to 0.5 m/sec." Flow velocity keeps striped bass eggs and larvae suspended in the water column which is their natural habitat. Lower flows would transport the critical life stage out of the microenvironment needed for proper development.

TABLE 3. REFERENCES FOR STRIPED BASS

1. Grant, G.C. and J.E. Olney. 1981. Assessment of larval striped bass, *Morone saxatilis* (Walbaum), stocks in Maryland and Virginia waters. Part II. Assessment of spawning activity in major Virginia rivers. Final Report, Segment 1, to the National Marine Fisheries Service, Gloucester, Mass. (Grant No. NA80FAD-VA1B), 39 pp.

2. Grant, G.C. and J.E. Olney. 1982. Assessment of larval striped bass, *Morone saxatilis* (Walbaum), stocks in Maryland and Virginia waters. Part II. Assessment of Spawning Activity in Major Virginia Rivers. Final Report, Segment 2, to the National Marine Fisheries Service, Gloucester, Mass. (Grant No. NA81FAD-VA3B), 42 pp.

3. Massmann, W.H., E.C. Ladd and H.N. McCutcheon. 1952. A biological survey of the Rappahannock River, Virginia. Part 1. Virginia Fisheries Lab, Gloucester Point, Virginia. 112 pp. (Mimeo).

4. Massmann, W.H., E.B. Joseph and J.J. Norcross. 1962. Fishes and fish larvae collected from Atlantic plankton cruises of R/V *Pathfinder*, March 1961-March 1962. Virginia Inst. of Mar. Sci. Spec. Sci. Rept. No. 33, 20 pp.

5. Merriner, J.V., A.D. Estes, and R.K. Diaz. 1980. Ichthyoplankton Entrainment Studies at Vepco Nuclear Power Station. Final Technical Report 1975-19787. Va. Inst. Mar. Sci., Gloucester Pt., Virginia. Section IIa and IIb, 602 pp.

6. Olney, J.E., B.H. Comyns and G.C. Grant. 1983. Assessment of larval striped bass, *Morone saxatilis* (Walbaum) stocks in Maryland and Virginia waters. Part II. Assessment of spawning activity in major Virginia rivers. Final Report, Segment 3, to the National Marine Fisheries Service, Gloucester, Massachusetts. (Grant No. NA81FAD-VA55B), 38 pp., Appendix I.

7. Rinaldo, R.G. 1971. Analysis of *Morone saxatilis* and *Morone americanus* spawning and nursery area in the York-Pamunkey River, Virginia. M.A. thesis, College of William and Mary, Williamsburg, Virginia. 56 pp.

8. Tresselt, E.F. 1952. Spawning grounds of the striped bass or rock, *Roccus saxatilis* (Walbaum), in Virginia. Bull. Bingham Oceanogr. Coll. 14(1):98-110.

9. Maryland Department of Natural Resources. 1986. 1985 Striped Bass Status Report.

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Temperature. Participants agreed temperature is a critical parameter. They noted that the criteria provided in the Strawman II document were too extreme. At 12° C, the larvae would stop growing; temperatures as high as 23° C would kill them. The group changed this criterion to "16 to 19° C."

pH. This parameter was determined to be critical, but the group agreed that not enough was known to set a criterion. They pointed out that the level in the Strawman II document was incorrect (pH = 6.5 causes great losses at low levels of alkalinity). This is a prime example of synergism; research has only recently detected this phenomenon.

Dissolved Oxygen. Participants agreed that DO is critical, but not enough is known to set a minimal level with confidence. A level of 5 mg/l is known to have no adverse effect on any life stage. Therefore, this level should be used until additional research findings can further refine the minimal level.

Ionic Constituent. The group was not sure whether ionic constituent was a critical habitat criterion by itself. The specific level in the Strawman II document was not discussed.

Turbidity and Suspended Solids. Turbidity was determined not to be generally critical. Levels for turbidity and suspended solids have been found not to be closely related, even though these variables are normally linked.

Bacteria. Participants agreed that the category of "Bacteria" should be changed to "Pathogens," since bacteria can be an indirect food source. No one knew of any data suggesting that striped bass larvae eat bacteria, so the group decided not to include bacteria as a food source.

Secchi Depth, Suspended Solids, Light Intensity and Chlorophyll. These parameters were determined not to be critical. (See Turbidity above for note on suspended solids level.)

Nitrogen and Phosphorus. Participants did not set any levels, but requested that the following points be noted concerning these parameters. "Ammonia, nitrites and any form of reduced nitrogen are known to be toxic. Nitrogen and phosphorus can have direct toxic effects on finfish, but the most critical impact is their collective effect on food production and anoxia in stratified waters. These factors must be taken into account when setting levels for these parameters for finfish."

PAHs. This parameter was designated as a "provisional critical parameter" pending more data. The group recommended Westin and Rogers (1978) (see Table 2) as a potential source of data on PAHs. Dr. Krantz also recommended reports from the U.S. Fish and Wildlife Service (USFWS) Laboratory in Columbia, Missouri, on toxicity tests on striped bass (Mehrle et al., in press; Mehrle and Ludke, 1984).

N/P Ratios and Carbon. N/P ratios and carbon were determined not to be critical to striped bass, but were primary driving factors in trophic dynamics upon which striped bass depend.

Metals. This parameter was designated as a "provisional critical parameter" pending more data. The group again recommended Westin and Rogers (1978) (see Table 2) as a potential source of data on metals. Reports from the USFWS Laboratory in Columbia, Missouri (Buckler et al., in press; Mehrle et al., in press; Mehrle and Ludke, 1984)) were also recommended. Aluminum and tributyltin were added to the list of metals of concern. Dissolved aluminum can impair gill structure and efficiency in young striped bass. Low pH can mobilize some metals. This is an excellent example of synergistic effects that were not included in the matrix.

Hardness. This parameter was determined not to be critical.

Alkalinity. Participants agreed this parameter is critical since it provides a buffering component to the ecosystem. They changed the level given in the Strawman II document to read "greater than or equal to 20 mg/l." They also noted that the optimum range was 70 to 200 mg/l calcium carbonate.

Herbicides, Insecticides and Chlorinated Hydrocarbons. The group decided that levels that would protect the most sensitive finfish species (probably the alosid) should be used for all species in the absence of species-specific data. Where data allow, levels should be set so that there is no biological impact. The levels set should minimize the possibility of intertrophic magnification and additivity of toxic chemicals as a result of chronic exposure. The chairman noted that, to date, not a single compound could be identified as a problem in the striped bass crisis. Dr. Richkus (Martin Marietta Environmental Systems) supplied data on 96-hr TL_m's for striped bass larvae and juvenile striped bass for many toxicants (Setzler et al., 1980).

Chlorine. Chlorine was added as a critical parameter, but no levels were set (i.e., any amount is considered to be detrimental).

Geographic Distribution. The group agreed that the geographic distribution of striped bass should be "as Maryland and Virginia have defined their spawning grounds by regulation." This distribution would be less restrictive than the maps provided. Dr. Krantz will supply maps of the striped bass spawning ground in Maryland. Dr. Barth (Virginia Marine Resources Commission) supplied the Virginia Marine Resources Commission regulation 450-01-0034 pertaining to the "taking of striped bass." The description of the critical reaches is provided in paragraph 3(c) on page 2, as follows:

> "Spawning reaches - sections within the spawning rivers as follows:
>
> 1. James River: from a line connecting Dancing Point and New Sunken Meadow Creek upstream to a line connecting City Point and Packs Point;
> 2. Pamunkey River: from the Route 33 bridge at West Point upstream to a line connecting Liberty Hall and the opposite shore;
> 3. Mattaponi River: from the Route 33 bridge at West Point upstream to the Route 360 bridge at Aylett;
> 4. Rappahannock River: from the Route 360 bridge to Tappahannock upstream to the Route 3 bridge at Fredericksburg."

5.3.2 Alewife/Blueback Herring

Background. Participants agreed that the criteria developed in this section would apply to the alewife, blueback herring and other alosids. Alewife populations have declined more than the blueback herring and are in greater need of restoration. The group agreed this section should be rewritten based on A.J. Lippson's compendium. Several documents (Krauthamer and Richkus, 1987a, 1987b, 1987c, and 1987d) were sources for the background narrative for the alewife.

Critical Life Stage. Both the egg and larval stages were determined to be critical.

Critical Life Period. The beginning of the critical life period was changed to "early March to the end of May."

Food. The group agreed that food is critical, but asked that the statement about larval feeding that appears in the matrix be deleted.

Substrate. The substrate was determined to be not critical for larvae, but critical for eggs and spawning since the blueback herring has adhesive eggs.

Cover. SAV was determined to be not critical for larvae or eggs.

Zone. This parameter was determined to be not critical.

Salinity. The group agreed that salinity is critical and that the 0- to 5-ppt range in the Strawman II document was acceptable.

Flow. Flow was determined to be not critical under natural conditions, but important under conditions created by sheer, power plant intake, pressure drop and dam turbines.

Temperature. The group agreed that temperature is a critical parameter. The range of 16 to 24° C was determined to be acceptable if it represents the lower and upper incipient levels of larval response to temperature.

pH. The group agreed that pH is a critical parameter. Members said the range of 6.5 to 8.5 appeared to be acceptable.

Dissolved Oxygen. Participants agreed that greater than 5.0 mg/l was an acceptable criterion for dissolved oxygen for the alewife but noted that this criterion would vary for different species.

Ionic Constituent. Not enough was known about this parameter to determine whether it is critical.

Turbidity. Turbidity was determined to be critical. Participants accepted the turbidity level of less than 50 NTU, but noted that two-thirds of the population might show decreased hatching success at this level.

Bacteria. The group noted that, although this variable was related to water quality and anoxia, by itself it is not critical for the alewife and herring.

Secchi Depth. This parameter was determined to be not critical.

Suspended Solids. The group agreed that suspended solids are critical to eggs. They changed the level to "50 mg/l."

Light Intensity. This parameter was determined to be not critical.

Nitrogen and Phosphorus. Participants did not set any levels for nitrogen and phosphorus, but requested that the following points be noted: "Ammonia, nitrites and any form of reduced nitrogen are known to be toxic. Nitrogen and phosphorus can have direct toxic effects on finfish, but the most critical impact is their collective affect on food production and anoxia in stratified waters. These factors must be taken into account when setting levels for these parameters for finfish."

PAHs, Metals, Herbicides, Insecticides and Chlorinated Hydrocarbons. These factors were considered to be "provisionally critical." The Atlantic States Marine Fisheries Commission Plan was referenced as a source for data on metals, herbicides, insecticides and chlorinated hydrocarbons.

Hardness and Alkalinity. Dr. Klauda (Johns Hopkins University) may have data on hardness and alkalinity for the blue herring, alewife and American shad. These data should be used in the absence of species-specific data.

Geographic Distribution. Concerning geographic distribution, the group recommended that Maryland's alosid management plan, which describes all known spawning areas, be used for distribution in Maryland. For all rivers with striped bass, the distribution for alosids should extend from the lower end of the spawning ground of the striped bass upstream to the headwaters of all tributaries, except where fish would run into a barrier, e.g., the West River and South River. In rivers in which striped bass do not occur, the distribution of alewives should be considered to go from the mouth of the river up to any upstream blockage. These rivers are listed on the River Herring Management Plan. The group recommended that distribution of alosids in Virginia be based on the spawning study by Dr. Loesch at the Virginia Institute of Marine Science. The group also recommended that the distribution of the alewife and herring as specified in the Pennsylvania regulations be included.

5.3.3 Atlantic Menhaden and Spot

Critical Life Stage. Following the workshop, Dr. John Merriner, National Marine Fisheries Service, Beaufort, North Carolina, was contacted regarding the critical life stage of the Atlantic menhaden. He said that the critical life stages were eggs and larvae on the Continental Shelf and post-metamorphic larvae and juveniles in the Chesapeake Bay.

Critical Life Period. The group accepted the critical life period as being from April to October.

Food. Food was determined to be critical, but the major food items were not discussed (see also Chlorophyll on the next page).

Cover. The group did not understand what was meant by "shallow waters." Participants felt that cover is not critical and queried whether the "shallow water" listing referred to the larval or juvenile stage.

Zone. Zone was determined not to be a critical parameter. The designation of zone was changed to "pelagic or open waters."

Salinity and Flow. These parameters were determined not to be critical. "Estuarine" should be deleted.

Temperature. This parameter was determined not to be critical. The limits were changed to "10 to 30° C."

pH. The group agreed this parameter is critical. They accepted the 6.5 to 8.5 range given in the Strawman II document and noted that the rate of change could affect survival. The effect of acid rain on pH levels in the Bay should be considered.

Dissolved Oxygen. Participants agreed this parameter is critical. They accepted the greater than 5 mg/l level given in the Strawman II document as a minimal incipient level.

Ionic Constituent and Turbidity. These parameters are not critical but can be lethal at extremes.

Bacteria. This criterion should be changed to pathogens. An infectious pancreatic virus and fungal parasites were mentioned as being pathogens of concern for the menhaden.

Secchi Depth, Suspended Solids and Light Intensity. These parameters are not critical because menhaden are found naturally in turbid areas.

Chlorophyll. Chlorophyll is critical as food, but no level was set. Phytoplankton cell size is critical, since menhaden are unable to filter sizes less than 12 to 20 micrometers.

Nitrogen and Phosphorus. Participants did not set any levels for nitrogen and phosphorus, but requested that the following points be noted: "Ammonia, nitrites and any form of reduced nitrogen are known to be toxic. Nitrogen and phosphorus can have direct toxic effects on finfish, but the most critical impact is their collective effect on food production and anoxia in stratified waters. These factors must be taken into account when setting levels for these parameters for finfish."

Carbon. Participants agreed that particulate carbon (as opposed to dissolved carbon) was tentatively critical as an indicator of primary productivity (and their algal-based food supply), and that it must be at a given level to sustain populations. They changed the title of the parameter to "Particulate Organic Carbon." This change should apply to all finfishes.

PAHs, Metals, Herbicides, Insecticides and Chlorinated Hydrocarbons. The Atlantic States Marine Fisheries Commission Plan was referenced as a source for data on metals, herbicides, insecticides and chlorinated hydrocarbons. The group deleted the levels given in the Strawman II document for metals, herbicides and insecticides.

Hardness and Alkalinity. These parameters are not critical.

Chlorine. Chlorine was added to the list of critical parameters. The group agreed that any amount of chlorine could be detrimental to the species.

Geographic Distribution. The distribution as indicated on the map that was supplied was incorrect. The menhaden is ubiquitous unless constrained by stream size or behavior.

5.3.4 Other Species

Once matrices had been completed for the striped bass, alewife/blueback herring, and Atlantic menhaden and spot, the group moved quickly through the other species. They felt the killifish would have many unique criteria. The hog choaker would be related to habitat requirements for the spot. Bay anchovies would be closely related to the menhaden responses to habitat.

5.4 Conclusions

Participants recommended assigning a two- or three-person team to each species. These teams would thoroughly research the literature and fill out the matrices, with references for each number. Then another workshop should be held to peer review the criteria, with the team present to defend the numbers.

6. WATERFOWL/BIRDS PLANNING SESSION AND TECHNICAL WORK GROUP

6.1 Approach

The waterfowl/birds planning session and work group were chaired by Dr. Matthew Perry, U.S. Fish and Wildlife Service Patuxent Wildlife Research Center. The group divided the bird species into three groups: ducks, wading birds and raptors. Participants filled out matrices for the canvasback and great blue heron and agreed that many of the criteria and comments for these two species also applied to other ducks and wading birds respectively. Some data were supplied for the redhead, the black duck and the wood duck. The raptors - eagle and osprey - were discussed separately. In assigning criteria, the group tried to find levels that would be protective of at least 75% of the population. During the work group session, Dr. Holland (Martin Marietta Environmental Systems) and Dr. Stevenson (Horn Point Environmental Laboratories) were consulted for information on benthic organisms and submerged aquatic vegetation, respectively.

6.2 General Changes and Recommendations

The work group eliminated some parameters for some species. The work group also changed some of the critical life periods, especially breeding times for canvasbacks and redheads in Canada. There was some discussion of what constituted a critical life stage; i.e., should it be the most critical stage during the time the birds are in the Bay area, or the most critical stage in their life regardless of whether it occurs while they are in the Bay. The group had difficulty discussing the ecological parameters for the food items, because most participants were not experts in these species. They recommended that such experts be present at any future workshops. Participants were uncertain what was meant by the terms "cover" and "zone" for bird species.

6.3 Waterfowl

Geographic Distribution. The group discussed whether geographic distribution should include areas where the species used to reside historically. They agreed that distribution should include areas of importance in the 1950s and should also list areas that are important in the 1970s and 1980s. The management goal should be to establish conditions throughout the 1950s distribution area that would make those regions amenable to the species again.

The group agreed that the loss of submerged aquatic vegetation in the upper Bay river systems had greatly reduced these areas as feeding portions of habitats for waterfowl, including the canvasback, redhead and black duck. Wood ducks are found mainly in upper tributaries bordered by trees, swamps, and marshes, and have been less affected by the loss of SAV in the upper part of the Bay. The upper Bay and the upper Potomac River are the areas of greatest concern for the ducks and need immediate attention and restoration. Hope was expressed for a return to pre-Agnes levels of SAV. The redhead has almost disappeared from the entire Bay. Populations of most duck species tend to be lower now than the high populations of the mid-1950's due to the changing habitats of the Bay.

Critical Life Stage and Period. The group decided that the critical life stage for all ducks would be the adult stage when they are wintering in the Bay. They felt that limited food sources during this period made this stage more critical than nesting. In accordance with this decision, all critical time periods for ducks were changed to "October through April."

Food. Some duck species have changed their food habits. The black duck and canvasback are feeding more on molluscan invertebrates. The redhead and widgeon have not changed their food habits but have almost disappeared from the Bay due to lack of SAV. Tundra swans and geese now feed on waste cereal grains in agricultural fields rather than on SAV.

6.3.1 Canvasback

The correct species name is "canvasback," not canvasback duck. The matrices should reflect this change.

Critical Life Stage. The critical life stage was changed to "wintering."

Critical Life Period. The critical life period was changed to "October through April."

Geographic Distribution. Traditionally, canvasbacks fed in the upper Bay early in the season and moved down the Bay as the water froze. Stewart's research in the 1950s (Stewart, 1962) indicates that the canvasback habitat covered the entire upper Bay at that time. Since the 1950s, the canvasbacks have wintered in the Susquehanna flats (historically), all eastern shore tributaries north of the Choptank, the middle Potomac north of Port Tobacco to Nomini Bay and Mobjack Bay. Historically, the upper Bay was the most important area for canvasback populations. Currently, the middle Bay (5 to 15 ppt salinity zone) holds the most canvasbacks because of adequate food reserves. A top priority for canvasbacks should be to restore them to the freshwater areas of the Bay.

Food. The group agreed that, historically, *Vallisneria americana*, *Potamogeton pectinatus* and *Macoma balthica* were all very important food species for the canvasback. *Potamogeton perfoliatus*, *Ruppia maritima*, *Zostera marina* and *Rangia cuneata* were of secondary importance. A survey of 323 canvasbacks from 1970 to 1979 (Perry, in press) showed that the canvasbacks' diet has changed due to changing availability of food species. In this survey, the predominant food of the 323 canvasbacks was as follows:

85% - *Macoma balthica*

5% - *Rangia cuneata*

3% - *Mya arenaria*

1% - *Leptocheirus plumulosus*

1% - *Nereis* sp.

2% - *Ruppia maritima*

1% - *Potamogeton perfoliatus*

Myriophyllum spicatum is not a food source for canvasbacks and should be deleted from the matrix. The group added crustaceans (including mud crabs, arthropods and isopods) as an important food species. They also tentatively added *Corbicula manilensis*, an Asian freshwater clam that is present in the Chesapeake Bay. Ducks eat these clams in Taiwan. It is not known if they are an important food source in the Chesapeake Bay. This could be an area for research.

Substrate. The group changed the substrate for *Ruppia maritima* to "prefers sand or silty mud."

Cover. The group was uncertain as to what "cover" meant for bird species. Members agreed that cover was not an applicable requirement for the canvasback.

Zone. The group was uncertain what "zone" meant in terms of bird species. Participants thought the figure of less than 3 meters seemed correct, but did not have the expertise to say so with certainty.

Salinity. The group changed the salinity criterion for Zostera marina to "5 to 35 ppt" and for Ruppia maritima to "5 to 60 ppt." (Higher salinity than sea strength may result due to evaporation in wetlands not inundated by daily tides.) Participants were unable to determine whether the other criteria were valid.

Temperature. The group expressed doubt about the accuracy of the temperature criterion given for Potamogeton pectinatus, Ruppia maritima, and Zostera marina. Dr. Holland said the optimum range for the Rangia cuneata was 10 to 15° C.

pH. Some food species experience germination problems below pH = 5. Participants thought 6 to 9 might be an acceptable range for pH for the food species, but were not sure. They also felt that pH might have an effect on Macoma balthica and Rangia cuneata and, therefore, the designation of "not limiting" for these two species in the Strawman II document might be incorrect.

Dissolved Oxygen. The group felt that "greater than 5 mg/l" might be an acceptable criterion for the six food species numbered 13.1 to 13.6 but were not certain of this. Members inserted a criterion of "5 ± 1 mg/l" for Macoma balthica, and changed the text for Rangia cuneata to read "Needs oxygen to live."

Ionic Constituent and Bacteria. These criteria were determined not to be applicable.

Turbidity. The group inserted a criterion of less than 20 mg/l for Vallisneria americana, Potamogeton pectinatus, Potamogeton perfoliatus, Zostera marina, and Ruppia maritima, and changed the text for Rangia cuneata to read "does well at high turbidity."

Secchi Depth. For Vallisneria americana, Potamogeton pectinatus, Potamogeton perfoliatus and Ruppia maritima, the group recommended that secchi depth should not be less than the depth to the bottom. They thought that secchi depth might not be a critical requirement for Macoma balthica and Rangia cuneata, but they were not sure.

Suspended Solids. The group referenced the Turbidity criterion.

Light Intensity. Dr. Stevenson thought the criteria given in the Strawman document for light intensity were low. He recommended that they be checked to make sure that the values given were for full saturation rather than half saturation. He thought that the numbers given probably came from the EPA Technical Synthesis Report, 1983, by Wetzel and Van Tine. If not, he suggested this reference be checked for comparison with the values given.

Chlorophyll. The group inserted a criterion of "less than 15 µg/l" for Vallisneria americana, Potamogeton pectinatus, Potamogeton perfoliatus, Zostera marina and Ruppia maritima. Dr. Holland commented that Macoma balthica does well at high levels of organics and that chlorophyll may be limiting for Rangia cuneata under conditions of low dissolved oxygen.

Nitrogen and Phosphorus. The general comment was made that these two requirements must be considered together. Levels of one affect species tolerance for the other. For freshwater species (Vallisneria americana and Potamogeton pectinatus), total dissolved nitrogen should be less than 1.4 mg/l in conjunction with phosphate levels of less than 0.003 mg/l. For mesohaline species (Potamogeton perfoliatus, Zostera marina and Ruppia maritima), total dissolved nitrogen should be less than 0.14 mg/l in conjunction with phosphate levels of less than 0.01 mg/l.

PAHs. Oil in the Sea (National Research Council, 1985) and an EPA report (U.S. EPA, 1980) were mentioned as sources of data on this parameter.

N/P Ratios. These were not discussed by the group.

Carbon. The carbon requirement was not discussed by the group except for the comment that Macoma balthica and Rangia cuneata do well at high carbon levels.

Metals. Dr. Holland stated that there is no evidence for biomagnification of any metals other than mercury up the food chain (Dillon, 1984).

Hardness and Salinity. The group specified a range of 10 to 30 ppt for Macoma balthica and 1 to 15 ppt for Rangia cuneata.

Herbicides, Insecticides and Chlorinated Hydrocarbons. These parameters were not discussed, except to say that SAVs are tolerant of insecticide levels.

6.3.2 Redhead

Critical Life Stage. The critical life stage was changed to "wintering."

Critical Life Period. The critical life period was changed to "October through April."

Geographic Distribution. Redheads currently winter around the Tangier, Smith and South Marsh islands off the eastern shore. Historically, they also resided in the same areas as the canvasbacks (i.e., throughout vegetated areas of the Bay). The participants agreed that they would like to see the redhead restored to these areas.

Food. The group agreed that Vallisneria americana, Potamogeton pectinatus, Potamogeton perfoliatus and Ruppia maritima were important food species, but were less important now than they had been historically. Participants considered Zostera marina to be the most important food species for the redhead at present. They deleted Myriophyllum pectinatus, Macoma balthica and Rangia cuneata from the list. The group noted that redheads also accidentally eat small snails attached to the SAV.

Other requirements of the redhead were not specifically discussed. However, the same SAV food species were listed for the redhead as for the canvasback. Thus, criteria for these species presented above under "Canvasback" also apply to the SAV food species for the redhead.

6.3.3. Black Duck

Critical Life Stage. The group changed the critical life stage to "wintering." Most black ducks breed in northern New England and eastern Canada (especially the Maritime provinces). Black duck populations are comparatively insignificant in Chesapeake Bay as a proportion of the total breeding population; nevertheless, they do have certain breeding areas which should be protected.

Critical Life Period. The group changed the critical life period to "October to April."

Geographic Distribution. Historically, there were large concentrations of black ducks in the Susquehanna flats and the eastern Bay region. Many habitats have been destroyed due to various forms of development and erosion along much of the eastern shore. Participants agreed that they would like to see the black duck restored to these areas at its 1950s population levels.

Food. The group agreed that *Vallisneria americana*, *Potamogeton pectinatus* and *Potamogeton perfoliatus* were important food species, but deleted *Myriophyllum spicatum*, *Zostera marina*, *Macoma balthica* and *Rangia cuneata* from the list. Participants were not sure how important *Ruppia maritima* was to the black duck. The group added marsh plants to the food species list and emphasized that these were a very important food source for the black duck. Dr. Perry also mentioned *Melampus bidentatus* (coffee snail) as a food source (Grandy, 1972).

Cover. The group cited emergent marsh vegetation (*Spartina* sp., *Zizania aquatica*, and *Iva*) and woody vines and shrubs as important cover for the black duck. Hunting blinds and trees also supply cover during breeding.

The group did not discuss other requirements for this species. The Strawman II document provides life history notes for the black duck.

6.3.4 Wood Duck

Critical Life Stage. The critical life stage was changed to "wintering."

Critical Life Period. The critical life period was changed to "October through April."

Geographic Distribution. The population status of the wood duck is reasonably good, but its habitats are in need of protection. The wood duck lives in forested fresh parts of most Bay tributaries on both the eastern and western shores from the wetland/floodplains to the river fall line. The group recommended that the wood duck be restored to 1950s distribution and population levels.

Food. Following the workshop, Dr. Perry listed four species as being major food species for the wood duck: *Peltandra virginica* (arrow-arum), *Sparganium eurycarpum* (giant burreed), *Polygonum* sp. (tearthumb) and *Quercus* sp. (oaks). He also provided data on salinity, flow, temperature and pH for these four species (see below).

Cover. Dr. Perry noted that cover is "needed for young."

Salinity. The salinity requirement for the four food species is 0 ppt since they are freshwater species.

Flow. The flow requirement for all four species is "tidal and nontidal."

Temperature. Temperature is not a limiting requirement for any of the four food species.

pH. pH for all four food species should be "less than 7.0."

Nitrogen and Phosphorus. Dr. Stevenson felt that nitrogen and phosphorus would not be limiting for the four SAV food species.

Other Requirements. No other requirements were discussed for the wood duck or its food species.

6.4 Wading Birds

The group felt that populations of herons and egrets were the same as they were in the early 1900s. Wading Birds (Sprunt et al., 1978) was mentioned as an information source. The references in Strawman II were also cited.

Geographic Distribution. Great blue and green-backed heron use the wooded tributaries for nesting areas, so geographically these areas are important (see Geographic Distribution for the great blue heron, below). The other herons and egrets use the islands, mostly south of the Bay Bridge in the middle part of the Bay. Smith Island up through island complexes (Hooper's) to the north are essential parts of the Bay for the island nesters. From the Bay Bridge north, there are almost no herons except the green-backed heron. The green-backed can be found in small numbers on many islands and tributaries in the Bay. Virginia has a large majority of its wading birds on the Atlantic side in protected areas (especially south of Chincoteague). Waders winter south of the Chesapeake Bay. There has been some habitat loss for the herons due to bulkheading and flooding of trees to create duck habitats, but the group did not know how important this loss was.

6.4.1 Great Blue Heron

Background. The Strawman II background text says that the minimum habitat for the great blue heron includes wetlands within a "specified distance (e.g., 1 kilometer)" of a heronry. One participant commented that a distance of 3 to 5 kilometers would be more suitable.

Critical Life Stage. The group agreed that the critical life stage is the nestling as indicated in the Strawman II document.

Critical Life Period. The critical life period for the great blue heron was changed to "May to July."

Geographic Distribution. The great blue heron has a widespread distribution, with many at Poole's Island, the Aberdeen Proving Grounds, and the Chester and Wye rivers. Upper tributaries and wooded swamps are important habitat areas for the great blue. The largest group of great blues (about 750 pairs) is on Nanjemoy Creek in the Potomac Nature Conservancy. Great blues are also found in Canoe Neck Creek, the north shore of the Potomac (very important), the upper portion of the Rappahannock, the upper Pocomoke on the Eastern Shore, the central Bay (South Marsh Island, the Smith Island complex, Tangier). Maryland has Critical Areas' guidelines of 1,000 feet riparian area for great blues and other waders. The group felt that current populations of the great blue heron should be maintained, but did not see a need to try to increase the population.

Food. The group agreed that all three food species listed - *Menidia menidia*, *Fundulus heteroclitus* and *F. majalis* - were very important. They also noted that the great blue heron is an extreme generalist and will eat many other kinds of food, including perch, rats, frogs and snakes.

Toxicants. Dr. Erwin (Patuxent Wildlife Research Center) felt that contaminants were not a problem, based on studies by five or six researchers in the last 20 years. However, he noted that there had been some local problems within five miles of contaminant sources.

Other Requirements. No other requirements were discussed for the great blue heron.

6.4.2 Little Blue Heron and Green-Backed Heron

The green heron is now called the green-backed heron.

Food. Toads and frogs are an important food source for these two species (Martin et al., 1951). No studies have been conducted of the food habits of the little blue or green-backed heron.

6.5 Raptors

6.5.1 Osprey

General. The osprey has recovered from DDT; however, recent reports show that osprey reproduction is reduced in the middle part of the Bay. Dr. Mitchell Byrd (College of William and Mary), Dr. Paul Spitzer (Horn Point Environmental Laboratories), and Mr. Jan Reese (St. Michaels, Maryland) were mentioned as experts on the osprey.

Geographical Distribution. Over 90 percent of the Bay is important for the osprey. There are some 1,500 pairs in the Bay area. They can be found in all coastal areas but not in deep water. They venture approximately 3 or 4 kilometers up tributaries and possibly farther up the Potomac. They live at least as far north as Miller's Island. Dr. Byrd and Dr. Reese can provide the limits of this habitat. Ospreys live on navigational buoys and duck hunting blinds; however, these structures have been decreasing in number. Ospreys breed during the summer and winter further south.

Food. The group agreed that *Brevoortia tyrannus* (menhaden) is an important food source for the osprey. However, commercial fishing of *Brevoortia tyrannus* has been increasing, particularly that of smaller size fish eaten by ospreys. In the last 5 to 7 years, researchers have seen nestlings fighting for food. The group felt that *Brevoortia tyrannus* experts should be involved with the aspect of the report dealing with the ospreys.

Metals. Mercury in fish was mentioned as a possible problem for the osprey. The group thought that Dr. Stan Wiemeyer at the U.S. Fish and Wildlife Service Patuxent Wildlife Research Center might have data on this.

Chlorinated Hydrocarbons. The group suggested that Dr. Wiemeyer may also have data relevant to the effects of chlorinated hydrocarbons on the osprey.

6.5.2 Bald Eagle

General. The eagle has recovered from DDT. Dr. J.D. Fraser (Virginia Technical University, Department of Fisheries and Wildlife Science, Blacksburg, Virginia), Dr. M. Byrd (College of William and Mary, Williamsburg, Virginia), and Mr. Keith Cline (Raptor Information Center, National Wildlife Federation, Washington, D.C.) were mentioned as sources of information on bald eagles. Two references for Bay eagles are *Bald Eagles in the Chesapeake: A Management Guide for Landowners* (Cline, 1975) and Andrew and Mosher (1982).

Geographic Distribution. The Bay area is a major resource for bald eagles during the nonbreeding season. Birds from the north (into Canada) and south (to Florida) and central Atlantic states use the Bay and tributaries. Important habitat features include fisheries, shoreline perches, and roost sites. The Potomac River, Caledon State Park on the Potomac (about 50 to 75 birds in summer), Aberdeen Proving Grounds (more than 100 birds), the Blackwater National Wildlife Refuge (20 birds), and the James River are important areas for the eagle. Bald eagles need a 1,500- to 5,000-foot buffer zone between their nesting area and development. Dr. Jim Fraser and colleagues are studying distribution, habitat use, and disturbance.

Food. The group added dead ducks as a food source for the bald eagle. This food source currently presents a problem because hunters still use lead shot, which can poison eagles that consume dead ducks. Lead shot will be illegal throughout the United States by 1991.

Cover. The group was not sure how this requirement pertained to the bald eagle, but they noted that the eagle needs a wooded area including snags (which serve the dual purpose of supplying nesting locations and observation points for prey surveillance).

Zone, Temperature, Dissolved Oxygen, Ionic Constituent, Turbidity, Bacteria. The group agreed that these parameters are not applicable to the bald eagle.

Chlorinated Hydrocarbons. The group suggested that Dr. Wiemeyer at Patuxent Wildlife Research Center may have data relevant to the effects of chlorinated hydrocarbons on the bald eagle.

7. BLUE CRAB TECHNICAL WORK GROUP

7.1 Introduction

The blue crab work group was chaired by Dr. John McConaugha, Old Dominion University. The group focussed on the blue crab, but pointed out that there are many other ecologically important crustacean species that participants did not have time to address.

7.2 Critical Life Stage and Period

The participants concluded that all life stages of the crab are important, in contrast with other species in which one life stage is critically sensitive. Crab larval stages are critical; however, they probably occur outside the Bay. The pre- and postmolt stages are critical for crustacea. Therefore, protective habitats must be available to protect the crab throughout its life. Other important factors include availability of cover (SAV), metabolic mobilization of toxicants, and increased risk of predators.

7.3 Background

Participants made several changes to the background text. The first sentence of the third paragraph was changed to read "All blue crab spawning occurs in Virginia waters." The last two sentences of this paragraph were changed to "Most females mate during the late summer season in July, August or September, and hatching is delayed until the following summer. A female may also produce two or more sponges of eggs later in the summer." The first sentence of the fifth paragraph now reads "Juvenile crab migrations up the Chesapeake Bay and its tributaries begin in August." The following paragraph was inserted between the sixth and seventh paragraph of the text:

> Molting is a major physiological event in the crustacean life history. Brachyurans molt frequently during the early juvenile stages (7-10 days). The periodicity decreases with age and increased size. Because the premolt and postmolt phases are periods of high metabolic activity, the animal may be more susceptible to environmental stress during these periods.

In addition, the group recommended that the background text (particularly the reference to migration in the second paragraph) be checked against key references. The publication Synopsis of Biological Data on Blue Crabs (*Callinectes sapidus*) (Millikan and Williams, 1984) provides an annotated bibliography of major references for the blue crab.

7.4 Matrix

Food

Blue crabs are hardy and eat any scavengeable material. However, the group concluded that food could be limiting under some circumstances for blue crabs. Seasonal changes and certain environmental conditions, such as low dissolved oxygen, may affect benthic organisms by limiting the surface area of their habitat. This reduced area may then affect crab survival. Important food species for crustaceans include: juvenile finfish, mysids, and small sand crabs. Low prey density may result in cannibalism. More attention should be paid to food web dynamics.

Cover

The group agreed that SAV may be important cover for juveniles and for molting crabs.

Zone

Crabs are found throughout the Bay, but there is a difference in distribution of males and females since the females migrate toward the Atlantic to release their eggs. Zone varies by season, life history stages and sex.

Salinity

Salinity is an important parameter for larval stages. The group accepted the 2 to 21 ppt levels given in the Strawman document for juveniles and adults.

Flow

The group felt that flow could have some long-term impact, particularly on spawning stocks in the lower Bay and on larval distribution and transport. Long-term alterations in salinity patterns may affect distribution of spawning females. This could alter larval distribution by changing the transport system.

Temperature

Extreme cold temperatures such as freezing over the Bay may increase juvenile mortality. The group discussed whether cold would have greater impact on animals that had not had adequate food, but no consensus was reached.

pH

This parameter was not discussed by the work group.

Dissolved Oxygen

The DO level was changed to "greater than 2 mg/1," because some participants suggested this was the level at which the benthic community started to be affected by low DO. Low DO could possibly restrict the available habitat of crabs, forcing them into shallow waters where they would be more concentrated, in which case available food would become limiting. Dissolved oxygen is important when seiches occur, spreading low-oxygenated water into shallow zones which endangers crabs and other species. The group did not have good data on the food web dynamics of this interaction, and thought it should be investigated.

Herbicides, Insecticides and Chlorinated Hydrocarbons

The group considered all three pollutants together. There is no good evidence that ecological levels of contaminants are affecting mortality of blue crabs. Contaminants may affect the behavioral response of crabs to other ecological parameters. Pollutants may also be important during the pre- and postmolt stages. Energy reserves are mobilized during these stages, so crabs would be exposed to the body burdens of the pollutants. On the Eastern Shore where fields overlap into the marsh, there may be some local effects due to high organophosphate concentrations in spring. This might be an appropriate area to conduct a study of pesticide residues in the crab.

The group said that more data were needed on the relationship between body burdens of pollutants in crabs and fecundity/embryo survivability; e.g., do pollutants in the yolk affect survivability and fecundity?

Other Factors

The group did not feel that most of the other factors (light intensity, secchi depth, turbidity, ionic constituents, suspended solids, chlorophyll, nitrogen, phosphorus, PAHs, N/P ratios, carbon, metals, hardness, alkalinity) had any direct impact on any critical stage in the blue crab; however, they may have indirect effects through the food chain and behavioral responses.

7.5 Geographic Distribution

The group suggested that any efforts to monitor the effects of environmental conditions on the blue crab focus on the lower Bay. This area includes the spawning grounds and provides the initial habitat for larvae/juvenile recruits entering from the shelf nursery grounds.

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APPENDIX A

WORKSHOP AGENDA

WORKSHOP ON HABITAT REQUIREMENTS FOR
CHESAPEAKE BAY LIVING RESOURCES

February 24, 1987
The Annapolis Ramada
Annapolis, Maryland

Sponsored by the
Chesapeake Bay Program's Living Resources Task Force

AGENDA

8:00 AM Registration and Chairmen Meeting

PLENARY SESSION

9:00 Welcome and Introduction
Living Resources Task Force Chair: Lee Zeni, Interstate Commission on the Potomac River Basin

9:15 Overview of the Workshop Approach and Objectives
Workshop Chair: Maurice Lynch, Chesapeake Research Consortium

9:30 Concurrent Planning Sessions

- Benthos
  Chair: Fred Holland, Martin Marietta Environmental Systems
- Plankton
  Chair: Kevin Sellner, Benedict Estuarine Research Laboratory
- Submerged Aquatic Vegetation
  Chair: Court Stevenson, Horn Point Environmental Laboratory
- Shellfish
  Chair: Roger Newell, Horn Point Environmental Laboratory
- Finfish
  Chair: George Krantz, Maryland Department of Natural Resources
- Waterfowl/Birds
  Chair: Matthew Perry, USFWS - Patuxent Wildlife Research Center

10:30 Coffee Break

10:45 Concurrent Technical Workgroups

- Marine Spawning Finfish/Anadromous Finfish
  Chair: George Krantz, Maryland Department of Natural Resources
- Molluscan Shellfish
  Chair: Roger Newell, Horn Point Environmental Laboratory
- Crabs
  Chair: John McConaugha, Old Dominion University
- Waterfowl/Birds
  Chair: Matthew Perry, USFWS - Patuxent Wildlife Research Center

12:00 PM Group Luncheon

1:00 Reconvene Concurrent Technical Workgroups

- Marine Spawning Finfish/Anadromous Finfish
  Chair: George Krantz, Maryland Department of Natural Resources
- Molluscan Shellfish
  Chair: Roger Newell, Horn Point Environmental Laboratory
- Crabs
  Chair: John McConaugha, Old Dominion University
- Waterfowl/Birds
  Chair: Matthew Perry, USFWS - Patuxent Wildlife Research Center

3:30 Coffee Break

CLOSING SESSION
Chair: Maurice Lynch

3:45 Chairmen present Summary Reports from the Concurrent Sessions and Workgroups

5:15 Closing Remarks: Review of the Workshop Proceedings Report and Continued Enhancement of Habitat Objectives
Maurice Lynch, Chesapeake Research Consortium

5:30 Adjourn

APPENDIX B

LIST OF PARTICIPANTS

WORKSHOP ON HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES

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February 24, 1987 - 9:30 a.m. to 10:30 a.m.

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WORKSHOP ON HABITAT REQUIREMENTS FOR CHESAPEAKE BAY LIVING RESOURCES

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February 24, 1987

10:45 a.m. - 12:00 p.m.
and
1:00 p.m. - 3:30 p.m.

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APPENDIX C

LIST OF LIVING RESOURCES TASK FORCE MEMBERS

LIVING RESOURCE TASK FORCE MEMBERS

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February 24, 1987

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APPENDIX D

ADDENDUM TO BENTHOS WORK GROUP REPORT

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THE REPRESENTATIVE IMPORTANT SPECIES (RIS) CONCEPT

It is not feasible to define habitat requirements for all biota inhabiting estuarine systems like the Chesapeake Bay. This is because the Bay consists of a diverse array of species that have a broad range of habitat requirements. Habitat requirements not only vary from species to species, but also vary from life stage to life stage within most species. In addition, habitat requirements vary geographically and seasonally. It is, however, generally possible to identify biota which, because of their abundance, distribution, ecological roles (e.g., food web linkage), or economic importance (e.g., commercially exploited species), are essential to, and/or representative of balanced indigenous populations of shellfish, fish, and wildlife. These target species or RIS can be used to focus definition of habitat requirements, making the assumption that if populations of these surrogate species are protected, then other populations and the ecosystem are protected. Because many RIS are near the top of estuarine food webs or are key links in food webs, changes in their abundance or distribution indicate system-wide alterations. However, for RIS to be reliable surrogates of habitat requirements, they must be selected carefully. For example, RIS selections should include biota that are sensitive to specific water quality parameters as well as biota that are representative of all major trophic levels. RIS should be selected from at least each of the following categories:

- Species sensitive to specific water quality parameters (e.g., dissolved oxygen or specific pollutants)
- Species using the habitats of the Bay as a spawning and/or nursery ground (e.g., species spawning in estuarine and freshwater habitats)
- Species of commercial and/or recreational value
- Species that are habitat formers and are essential to maintaining important ecosystem functions (e.g., submerged aquatic vegetation)
- Species that are important linkages in the food web
- Species recognized as threatened or endangered
- Nuisance species likely to be enhanced by changes in water quality or other habitat requirements.

RIS should also be selected to include:

- Primary producers and zooplankton
- Benthos
- Forage fish
- Predatory fish
- Other vertebates.

Definitions and protection of habitat requirements of only "celebrity" species may not adequately protect essential ecosystem functions.

BENTHOS

Importance of Benthos

The Chesapeake Bay is home to an active community of organisms which live in association with bottom sediments. This assemblage, collectively known as the benthos, includes familiar organisms such as oysters, clams, and crabs, as well as less familiar forms, including segmented and unsegmented worms, small crustaceans, snails, and anemones. A large portion (~75%) of the living and dead organic material in the Chesapeake Bay water, including the plankton and decaying plant material washed in from the watershed, settles to the sediment surface and decays. This decaying material is the major food source for benthic organisms. As benthic organisms burrow through the sediments to obtain this food, they alter sediment characteristics. In addition, as a result of burrowing and feeding activities, a portion of the nutrients and other chemicals buried in the sediments are returned to the overlying water. Recycled nutrients frequently contribute to excess phytoplankton production and eutrophication, and recycled chemicals can contribute to local toxic problems and degraded water quality. The Chesapeake Bay is a nursery ground for many commercially and recreationally important fish. While on their nursery grounds, many of these fish feed almost exclusively on the benthos. In conclusion, benthic organisms are a Representative Important Trophic Group forming important links between primary producers and higher trophic levels and are an integral part of the Bay food web.

Salinity/Dissolved Oxygen

Salinity is the major natural environmental factor controlling regional distributional patterns for the Bay benthos. Differences in sediment characteristics and in the levels of bottom dissolved oxygen concentration that occur from shallow to deep habitats control local benthic distributions as well as differences in benthic communities that occur from the upper Bay to the lower Bay. Most of the lower Bay (i.e., downstream of the Rappahannock River), and high salinity regions of lower Bay tributaries, are characterized by a diverse mix of species, including deep-burrowing, longer lived species. Most of the upper Bay is, however, characterized by shallow burrowing, highly-productive, short-lived species. The benthic species assemblage occurring in the upper Bay is similar to that characteristic of eutrophic or stressed environments.

Types of Benthic Communities

Several major assemblages of benthic populations occur along the Bay's salinity and sediment gradients. These are: (1) a tidal freshwater assemblage (sand and mud), (2) a trace salinity assemblage (sand and mud), (3) a low salinity estuarine assemblage (sand and mud), (4) a high salinity estuarine sand assemblage, (5) a high salinity estuarine mud assemblage, (6) a marine sand and muddy-sand assemblage, and (7) a marine mud assemblage. The tidal freshwater assemblage is limited to the upstream portions of Bay tributaries. Aquatic earthworms, called oligochaetes, and larval insects are numerically dominant in this habitat. The trace salinity assemblage occurs in the transition zone between tidal freshwater and estuarine habitats. It is of greatest extent in the upper portions of the mainstem Bay and the Potomac and James rivers,and is of limited extent in smaller tributaries. A mix of freshwater organisms which tolerate exposure to low salinity, and estuarine species which tolerate exposure to freshwater are abundant in the trace salinity habitat. The low salinity estuarine assemblage is dominated by estuarine species. A few marine species that tolerate exposure to low salinity also occur in lower salinity regions of the Bay. The high salinity estuarine sand and mud assemblages are distinct assemblages, each dominated by marine species that tolerate exposure to low salinity. The marine sand and muddy-sand assemblages occurs over much of the lower mainstem Bay and consists mainly of deep-burrowing polychaete worms. Epifaunal organisms are frequently attached to the tubes of some of these deep burrowing biota. Most of the species inhabiting high salinity assemblages do not tolerate exposure to low salinities. The marine mud assemblage mainly occurs in deep channels of the lower Bay and near the mouths of lower Bay tributaries. Polychaete worms also dominate this habitat.

Geographic Distribution

The spatial distribution of benthic biomass for the Maryland Bay is summarized in Fig. 1. The height of the bars represents the average annual amount*of benthic biomass per square meter of bottom area. The deep central portion of the Bay and the lower half of the Potomac River support the lowest benthic biomass. Low benthic biomass also occurs in the deeper regions near the mouths of smaller tributaries. In these habitats. annual abundance and biomass of benthic organisms is depressed because of adverse effects associated with oxygen-depleted (i.e., anoxic) bottom waters that occur during warmer months. The effects of anoxia on the benthos are most apparent just downstream of the Bay Bridge where anoxia is generally most severe and of greatest duration. Benthic organisms occurring in habitats that experience anoxia are small, rapidly-growing forms that can reproduce in any season.

*In gms ash-free dry wt/m^2.

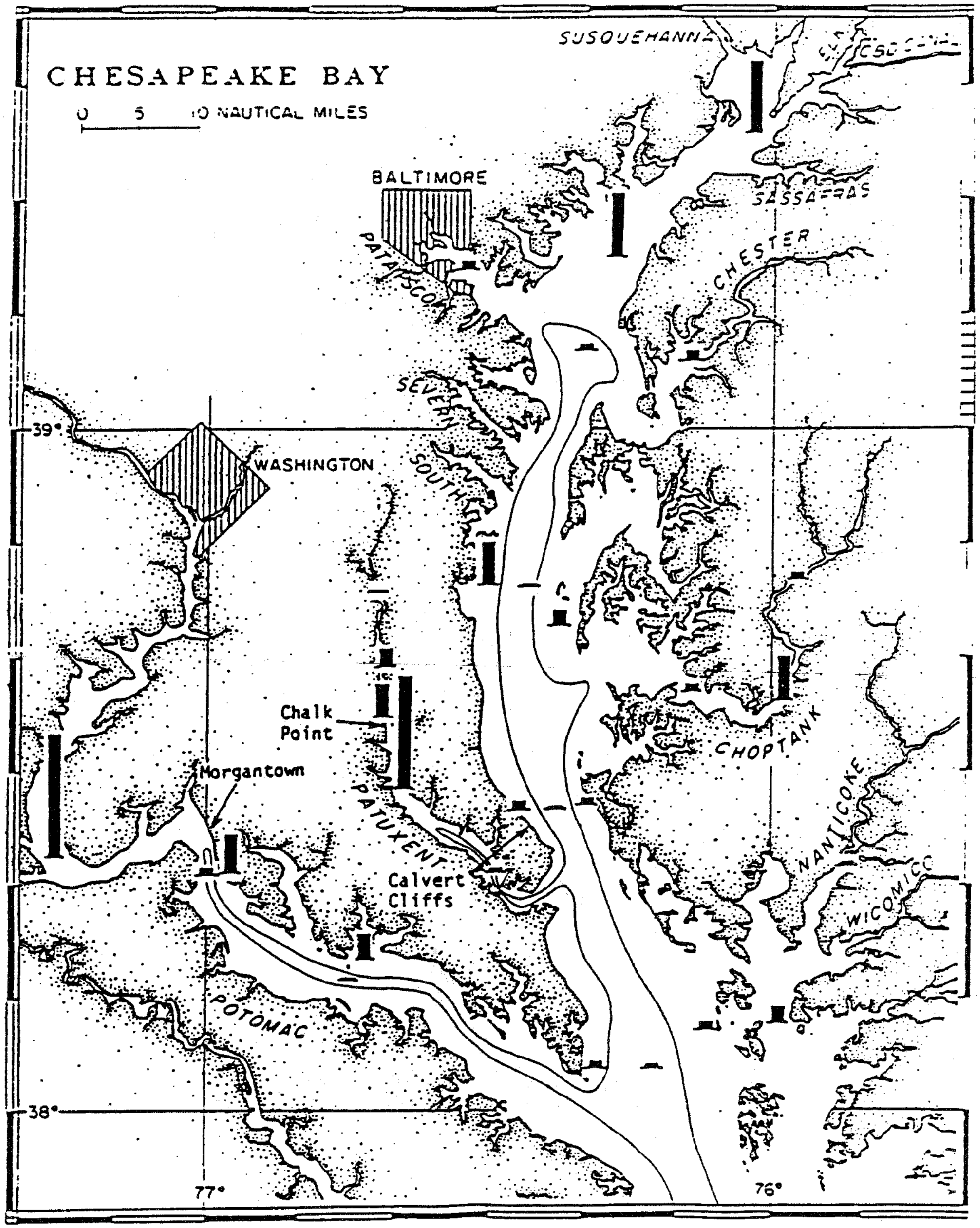

Figure 1. Spatial distribution of average annual benthic biomass in the Maryland portion of Chesapeake Bay. Bars are average values* when multiple stations occurred in a region. The shaded contour shows the region affected during the summer by anoxic bottom waters.

*gms ash-free dry wt/m^2.

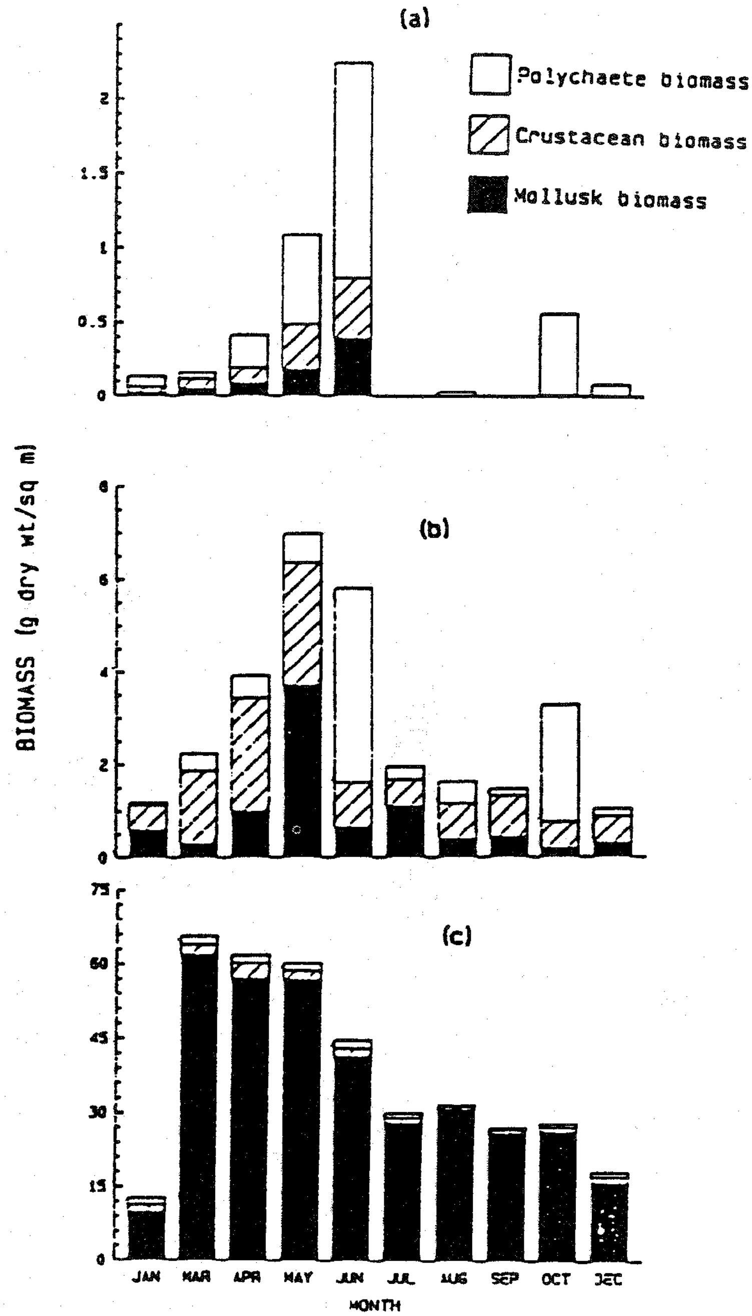

Figure 2. Seasonal fluctuations in benthic biomass for representative habitats. (a) high salinity sand habitat, (b) high salinity mud habitat, (c) low salinity estuarine assemblage.

Shallow habitats along the margins of the upper Bay and the lower half of the Potomac River do not experience summer anoxia and are characterized by much greater benthic biomass than the adjacent deeper habitats that experience summer anoxia. A variety of benthic organisms are abundant in shallow habitats including small, rapid-growing polychaetes and larger, slower-growing crustaceans and mollusks. These habitats are the primary nursery grounds for juvenile fish. Most of the lower Bay does not experience anoxic waters and benthic biomass in these habitats is high throughout the year. These habitats are also important feeding and nursery areas for fish and crabs.

The greatest biomass of benthos, represented by the tallest bars in Fig. 1, occurs in trace salinity and low salinity estuarine habitats. Much of the suspended sediment and organic inputs to the Bay is deposited in this habitat. The Macoma clam, _Macoma balthica_, and the brackish water clam, _Rangia cuneata_, comprise most of the benthic biomass in the zone of maximum turbidity. These clams are particularly well adapted to feeding on micro-organisms associated with organically rich, frequently resuspended sediments.

Seasonal Variation

The biomass of benthic organisms at any one place in the Bay fluctuates as much or more over an annual cycle than from place to place. Figure 2 summarizes month-to-month variation for the benthos of typical Bay habitats. In all habitats, peak benthic biomass occurs in the spring (Fig. 2). Factors influencing within-year variation in benthic biomass vary among habitats. Essentially no benthic organisms survive anoxic conditions that occur in deep habitats during summer (Fig. 2a). When anoxic conditions dissipate in early fall, deep habitats are repopulated within weeks by small, rapidly growing polychaetes. Benthic biomass is also low during summer in shallow habitats along the margins of the Bay and its tributaries. Summer low biomass values in shallow habitats are, however, larger than peak biomass values in deep habitats that experience anoxia (Fig. 2a and 2b). A variety of taxa contributes to biomass peaks in shallow habitats, including polychaetes, crustaceans, and mollusks. Seasonal variation in benthic biomass is reduced in the trace salinity habitat; however, biomass levels in this habitat are always an order of magnitude higher than those in other habitats.

Benthic Organisms as Water Quality Indicators

In the Patuxent River, the abundance of adult _Macoma_ clams peaked in 1978-1980 near the zone of maximum turbidity at the same time that suspended sediment and sewage loadings were at the highest levels recorded for this system (Fig. 3). As discussed above, Macoma biomass is closely linked to the amount of organic material that is produced within or input to the system. Patuxent Macoma populations have declined since 1980 as suspended sediment loadings have declined and as sewage treatment facilities have been upgraded. Declining Macoma biomass indicates that the amount of organic material accumulating in Patuxent sediments is decreasing and overall water quality is improving. These data suggest that pollution abatement and cleanup programs for the Patuxent River are effectively improving water and sediment quality by limiting inputs and production of organic material. These trends are not, however, related to specific changes in water quality parameters (i.e., reduced inputs of pollutants), but are rather associated with overall improvements in water quality (e.g., increased dissolved oxygen decreased turbidity, reduced chlorophyll, etc.). The benthos are responding in a measurable and interpretable way to these improvements and appear to be an early indicator of system-wide improvements.

Salinity

Natural effects of salinity fluctuations on long-term benthic abundance trends are shown in Fig. 4 for the low salinity estuarine assemblage from the middle reaches of the Potomac River. This figure suggests that year-to-year fluctuation in salinity during the reproductive periods is a major factor influencing long-term trends for benthic organisms. Salinity exerts the most influence over benthic distributions during early life stages shortly after reproduction because these life stages generally have narrower salinity tolerance ranges than do adults. Long-term benthic responses to salinity and other sources of natural variation (e.g., climate) can and must be determined before benthic habitat requirements can be defined.

Synergism Among Parameters

Figure 5 summarizes the responses of an abundant Bay benthic species, Macoma balthica, to temperature, salinity, and the impact of man-induced pollutants. The response pattern should be typical of that for most other Bay biota, including fish and other benthos, and shows the complex interactions that exist between natural water quality parameters and man-induced water quality changes. If more than three natural and man-induced factors had been included in the experiments shown in Fig. 5, responses would have been more complex. This information suggests that definition of specific habitat requirements for estuarine biota is complex and that determination of values for specific habitat criteria is impractical given present

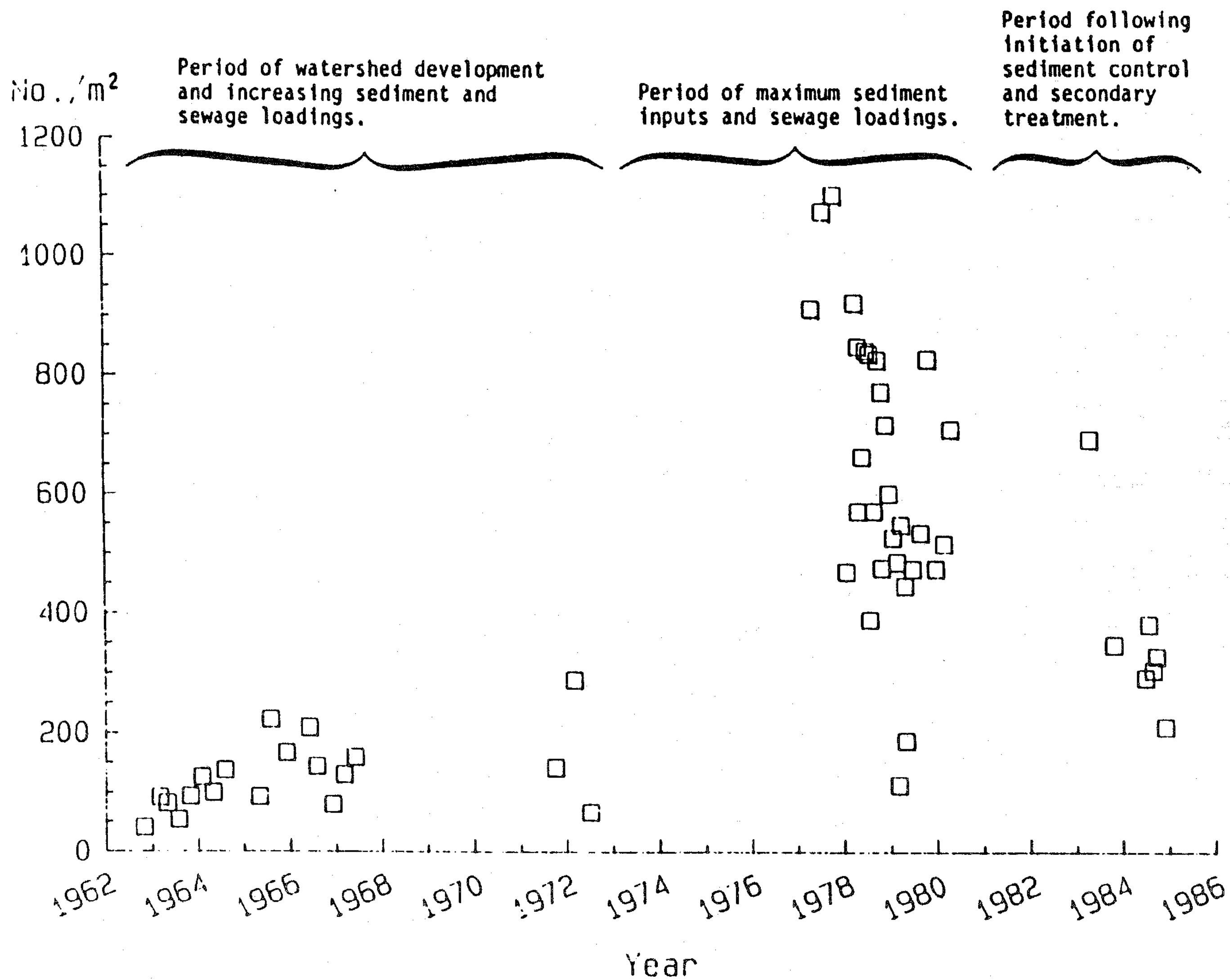

Figure 3. Long-term abundance pattern for adult Macoma balthica in the region of the turbidity maximum of the Patuxent River. Gaps between data points indicate years when data were not collected.

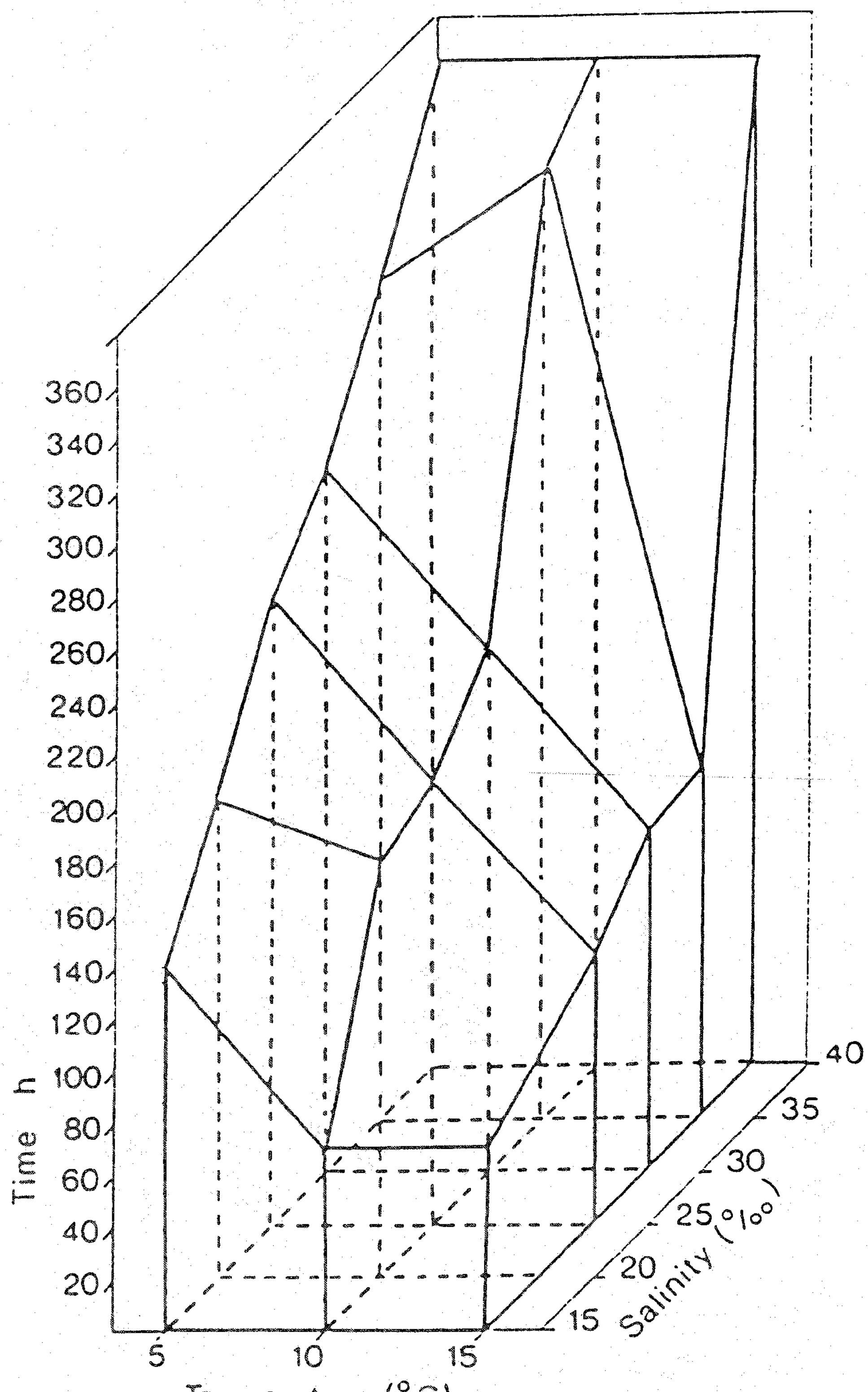

Figure 5. The effect of temperature and salinity on median survival time (h) of Macoma balthica at a chromium concentration of 64 mg/l^{-1} (after Bryant, McLusky, Roddie and Newberry, 1984)

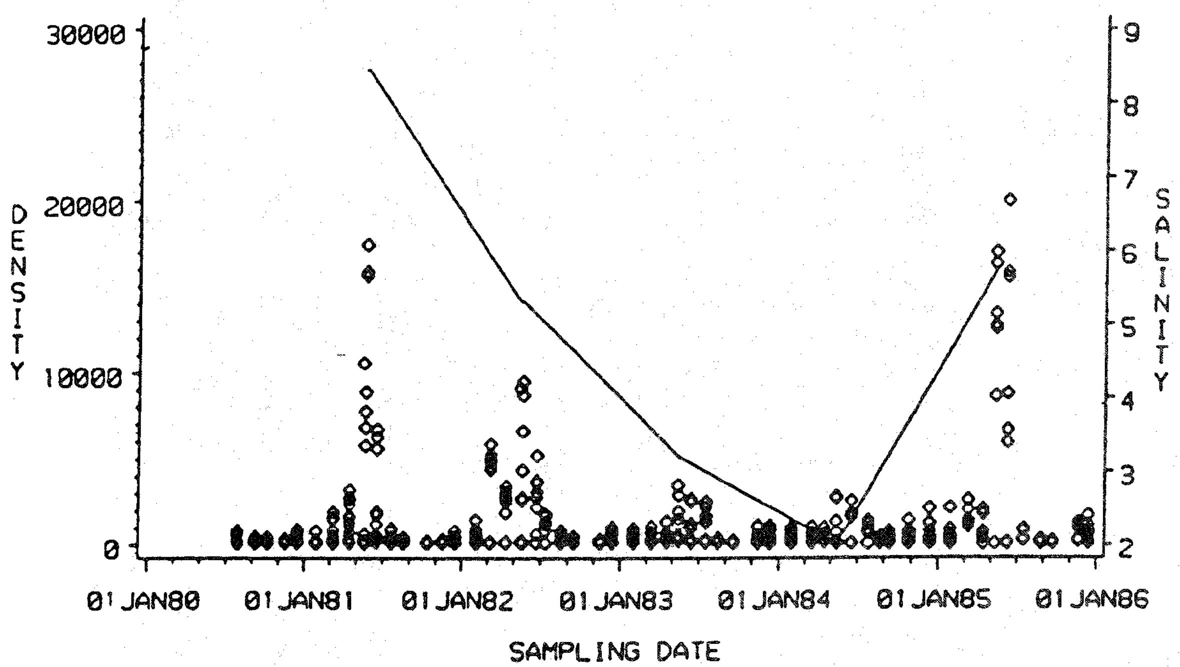

Figure 4. Long-term abundance pattern for the small crustacean. Leptocheirus plumulosus, in the low salinity estuarine region of the Potomac River. Note the relationship between the magnitude of reproductive pulses and salinity during the reproductive period.

knowledge. Rather, it is more practical to use this type of information to identify habitat requirements and water quality parameters to which the biota are particularly sensitive and that can be influenced by resource management actions. It may then be possible to define the important habitat characteristics of the benthos (or other biota) that the resource manager can strive to attain. It may then be possible to develop standards that protect these sensitive habitat requirements.

Benthos as Water Quality Indicators

The composition of Bay benthic communities is determined by ambient sediment and water quality. Therefore, the makeup and abundance of organisms composing benthic communities are likely to respond to changes in water and sediment quality resulting from inputs of pollutants, pollution abatement programs, or other management actions taken to improve the Bay's water quality. Because many benthic organisms live for 1-2 years, changes in their populations are an integration of changes in environmental conditions occurring over their life span and are frequently better indicators of water quality than direct measurements. In addition, because benthic organisms are relatively immobile, they complete their life cycle within the Bay and often within specific regions of the Bay. Thus, benthic responses to changes in water quality are likely to be region specific and easily interpreted. Finally, as important intermediate links in the Bay food web, benthic responses to water quality changes are likely to be representative of the responses of other living resources. The benthos are, therefore, good indicators of overall water quality and protection of their habitat should ensure protection of most other Bay biota.

Conclusions

- Benthic organisms are an important component of the Bay ecosystem, serving as food for fish and crabs and mediating exchange processes between bottom sediments and the overlying water column. They should be considered a Representative Important Group for Chesapeake Bay. Protection of the benthic habitat is essential to maintenance of a balanced Bay ecosystem.

- Benthic organisms provide a sensitive indicators of water and sediment quality that integrates over trophic levels, over time, and over a number of important environmental variables. Protection of the benthic fauna should thus result in protection of many other fauna.

- The impact of low dissolved oxygen waters on bottom habitats is difficult to measure directly but is clearly evident in benthic communities.

- The long-term response of benthic organisms to reductions in organic inputs and initial clean-up of the Patuxent River has been documented and appears to be favorable.

- Benthic responses to pollution abatement can be accurately tracked because natural sources of variation are known and can be partitioned from responses associated with pollution abatement and cleanup programs.

- Interaction between natural environmental conditions and man-induced pollutants is complex and affects the impact of pollutants in biota. These interactions must be considered when establishing habitat requirements.

APPENDIX E

ADDENDUM TO THE SHELLFISH PLANNING SESSION AND TECHNICAL WORK GROUP REPORT

By John Kraeuter
Baltimore Gas and Electric Company

APPENDIX E

ADDENDUM TO THE SHELLFISH PLANNING SESSION AND TECHNICAL WORK GROUP REPORT

An important functional aspect of Chesapeake Bay is the seasonal cycle. Freshwater input to the system in a pulsed fashion is essential for maintaining oyster beds. Predator and disease control on oyster-producing areas is, in part, controlled by the wet and dry years experienced by the system. It is important that this system behavior not be disrupted. The fact that this varies in intensity from year to year is vital to oyster production. Years of very strong spring flow may push predators and diseases farther down the Bay. This same process may kill small, diseased or otherwise weakened oysters. If the process lasts long enough, it may eliminate an entire year class. Mature oysters are more resistant to such pulses. They maintain the integrity of the bed, so it is better able to support the next few years' spatfall because of lack of predation and disease. Because of these natural cycles and lack of consistent spatfall, the farthest upstream bars cannot support intense harvesting pressure.

Harvest pressure on oyster bars must be scaled to the natural processes supplying oysters, nutrients and environmental perturbations to the system. An appropriate model for the freshwater input to the Bay would be the historical salinity or freshwater inflow scaled by the river system (with perhaps the exception of major events such as Agnes). The point of using the records for each system is that, although the entire drainage basin tends to act in much the same way, a very intense pulse one year in the James River may not be matched by that in the Susquehanna.

The increase in nutrients in the spring brought about by runoff is also important to the "scaling" of that year's processes. While the Bay is now clearly too eutrophic, management should reduce nutrient and silt input without disrupting the pulses of freshwater and without disrupting the natural cycles of nutrient pulses. An equal percentage reduction in each time unit is preferable to a concentrated effort in any one time unit. Space and time scale ecological processes and are interrelated. Resource managers should be very careful when manipulating such processes.

APPENDIX F

GENERAL COMMENTS ON THE MATRIX APPROACH TO DEFINING HABITAT REQUIREMENTS

GENERAL COMMENTS ON THE MATRIX APPROACH TO DEFINING HABITAT REQUIREMENTS

Several participants individually and collectively commented on the matrix approach to resource management. These comments are summarized here.

1. Users of the data - planners, etc. - should be present at future workshops to provide guidance to scientists on the kinds of data needed.

2. There were many errors in Strawman II that made scientists uneasy about the quality of the final product.

3. All data in the matrices should be carefully referenced and documented. References should be attached to the report.

4. In order to fill out the matrices, a study team should thoroughly research the literature and fill in the matrices based on the best data currently available. Then, a second workshop should be held to peer review the numbers they have selected. The individuals who compiled the data would defend the data at the workshop.

5. For matrices where the key species and food species are different (e.g., birds that feed on plants), experts in the food species should fill out the matrices rather than experts in the key species.

6. The Strawman approach does not make allowances for synergism among the parameters.

7. Key species should include all important species, not just those that are endangered or politically important. Even if a species is doing well now, we should know what criteria are protective to guard against future changes and threats to the species.

8. The terminology in Strawman should be clarified. For example, what is meant by "substrate?"

9. It is difficult to put single numbers into the matrices because these may change under different conditions.

10. If standards are set based on target species, the needs of species that were not examined may not be addressed. All species should be examined.

11. Many of the matrix elements were irrelevant for some of the key species.

12. For many species, several life stages or the entire life cycle are critical.

13. The species designated as key need to be reevaluated.

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